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THE STEINBACH CAVE NEAR SULZBACH.

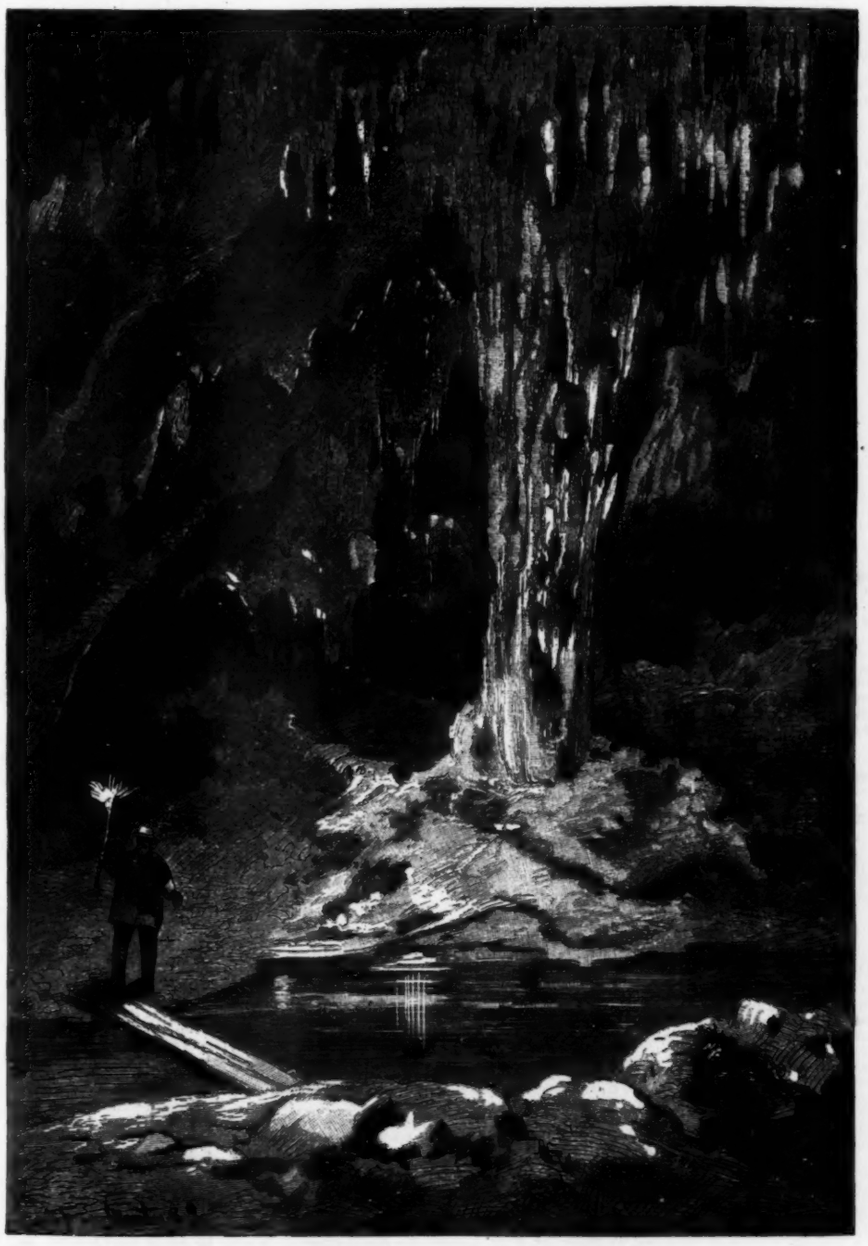
ANY one who has wandered through Frankish Switzerland, with its gently rising heights and picturesque ruins, certainly cannot have neglected to visit one of the caves of the region—either the Schonsteinhohle or the Sophienhohle—to see the stalactite formations and fossil remains.

The caves of Frankish Switzerland have been known for ages, and, therefore, it seems very strange that only a year and a half ago another cave, of which scarcely anything was known before, was discovered in Steinbach near Sulzbach. It can be reached by the railroad which runs from Nurnberg through the valley of Pegnitz, and then turns at Pommelsbrunn into a romantic valley. On this route we see the ruins of Rupprechtstein and Castle Neidstein, and the old villages of Etzelwang and Neukirchen.

The mountains here are considered the last spurs of the Jura range. Starting from Neukirchen a good pedestrian can reach the Steinbach Cave in about an hour, the walk being a true delight to the lover of nature, for beautiful views present themselves on every side, and refreshment can be obtained at a charming little inn, "Zur Waldlust," in the woods. Descending the valley, he comes upon the old castle Holnstein, and soon after reaches his destination, the grotesque entrance to the Steinbach Cave.

Formerly the inhabitants knew only of a cave which was a yard deep, in which their ancestors concealed their possessions during the wars of Napoleon. The discoverer of the real cave is a certain Appel, a tailor of Steinbach. He spared neither trouble nor expense in clearing the cave of rubbish and making it accessible by means of stairways.

The tourist draws on loose trousers and a linen jacket over his traveling suit, wraps a cloth around his head, and starts, looking like a North Pole explorer, through the newly made entrance of the cave, following his guides with their torches. He descends seventy feet by no less than five staircases, and is surprised at every turn by strange pictures, wonderful formations of ivory colored stalactites. They hang from the ceiling like gigantic elephants' trunks, ready to catch the intruder and hold him back from their secrets. If touched with a stick, these stalactites give forth odd sounds, which seem like a wail from remote ages.



DER WASSERFALL (THE WATERFALL).

Our cuts show the most interesting formations, namely, the "Reichspalast" (Imperial Palace) and the "Wasserfall" (Water Fall). When seen by magnesium light these formations are indeed fairylike, and would give a scene painter most beautiful models for the last scene of "Undine." Not the slightest noise from the upper regions penetrates the quiet of this strange nether world, where the stillness of the grave is broken only by the falling of the drops of water from the stone to the surface of the little lake which lies in the depths of the cave.

The feelings called forth by the beauty and wonder of the surroundings are somewhat modified by the numerous piles of bones and skulls lying about and partly embedded in the walls. Who placed them there and how many years they have been there no one can tell. The tradition among the inhabitants is that the Huns left their dead here when they passed through the country.—*Illustrirte Zeitung.*

A SWEDISH METEORITE.

AT a recent meeting of the Swedish Geological Society Prof. Nordenskiold showed the meteorite which fell at Sundsgard, a few miles from Engleholm, Sweden, on April 9, 1889. The meteorite was secured at once for the Swedish State Museum at a considerable sacrifice, and the circumstances of the fall were described by several eye witnesses. Some described the sound as an explosion or a shot from a cannon, after which a sort of piping sound appears to have been heard, like an organ, says one of the witnesses. The light of the meteorite was extinguished with the explosion. The meteorite was, as usual, surrounded by a melted shell, the result of the friction against the atmosphere. Otherwise it consists of a heavy grayish lump, about the size of a head, evidently only forming a fragment of an original larger body. It consists of chondrite, with specks of metallic iron.

THE PREPARATION OF MICROSCOPICAL SECTIONS FROM BARKS AND ROOTS USED IN PHARMACY.

AT a recent meeting of the London Chemists' Assistants' Association, the following paper was presented by M. J. Cole:

Barks and roots that have been dried must be cut into small pieces and soaked in water for several hours. This will cause the tissues to swell up and regain to a certain extent their natural shape. They are then to be transferred to methylated spirit, which should be changed every twenty-four hours until no color comes away from the tissue. They will then be ready for cutting into sections, or they may remain until required.

Fresh specimens should be cut into small pieces and placed in methylated spirit, which should be changed until no color is given off from the tissue. The hardening will usually be complete in a week, or they may remain for any length of time until required for cutting.

Some barks will be found too hard to cut; they may be softened by soaking for a time in liquor potassæ, then wash well in water until all trace of potash is removed.

Section Cutting.—Fairly good sections may be made by hand with an ordinary razor. Hold the piece of tissue in the left hand, keeping the forefinger straight, so that it may form a rest for the blade of the razor to slide on. A good strong army razor answers very well. Hold it firmly in the hand and keep the handle in a line with the blade, and draw it from heel to tip through the tissue toward yourself. Keep the blade well wetted with dilute methylated spirit, and as the sections are cut, place them in a saucer of spirit or water.

Section Cutting with a Microtome.—If really good sections are required, a microtome of some kind should be employed. A very good and complete instrument, capable of being used for making all kinds of microscopical sections, can be obtained from Messrs. W. Watson & Sons, of 313 High Holborn. Screw the microtome to a firm table, and, with the tube supplied with the machine, punch out a cylinder of carrot to fit the well of the microtome. Cut this in half longitudinally, and scoop out sufficient space in one half to take the tissue to be cut. Put the other half of carrot in its place, and make sure that the tissue is held quite firmly, but it must not be crushed. Now place the whole in the well of the microtome and commence to cut the sections with a strong razor, or the section knife that is supplied with the machine. When desired, keep the blade of the knife well wetted with dilute spirit, and as the sections are cut place them in a saucer of spirit or water.

Bleaching.—Vegetable sections generally require bleaching before they can be properly stained. A solution of chlorinated soda is usually used. Soak the sections in distilled water to remove the alcohol. Pour off the water and add a quantity of the bleaching solution, and allow it to act for from three to twelve hours, or until all color has disappeared from the sections, then transfer to water,

which must be changed several times until all trace of soda is removed.

Staining Sections.—The best staining fluid for general purposes is logwood. Take two ounces of ground logwood chips, place them in a calico bag, and run water through it until scarcely any color comes away. Drain away as much water as possible, remove the logwood from the bag and spread it in a thin layer on a tray to dry. Dissolve two drachms of potash alum in twelve ounces of distilled water. Put the logwood into a vessel, pour on the alum solution, and let it stand for forty-eight hours. Strain through muslin, and add four ounces of glycerin and one ounce of rectified spirit, mix well together, filter through paper, and add a small lump of camphor to make the mixture keep. Place the section in distilled water.

Add from thirty to forty drops of the logwood solution to an ounce of distilled water, filter, and immerse the section for three or four hours. Wash well in distilled water and then soak for a short time in ordinary tap water to fix the color.

Transfer to methylated spirit for ten to fifteen minutes to dehydrate.

Take a small saucer or watch glass full of clove oil and carefully float the section on to the surface of the oil and let it soak for five or ten minutes. When quite clear, wash in turpentine and mount in Canada balsam.

The logwood solution may be used undiluted for quick staining, but better results are obtained by the slower process.

Mounting in Canada Balsam.—Take four ounces of dried Canada balsam and dissolve in four fluid ounces of benzol, filter, and keep in a good outside capped bottle.

Clean a slide, place some balsam on its center, take the section from the turpentine with a lifter, and place it in the balsam on the slide. Now clean a cover glass, and with a pair of forceps bring its edge in contact with the balsam on the slide; ease it down carefully so that no air bubbles may be inclosed, and press down until the section lies quite flat. Now put the slide away for a day or two so that the balsam may set, and then take a soft brush and with some benzol wash away the exuded balsam from around the edge of the cover. Allow the slide to dry and apply a good coat of gold size, and when this has dried wash the slide with some soap and water, dry well with soft cloth, and add a coat of asphalt.

Double Staining.—

Aniline Acid Green Stain.

Acid green	2 grains.
Distilled water	3 ounces.
Glycerin	1 ounce.

Mix the water and glycerin well together and dissolve the green in the mixture.

Carmine Stain.

A.

Borax	10 grains.
Distilled water	1 ounce.
Glycerin	½ ounce.
Alcohol	½ ounce.

Dissolve the borax in the water and add the glycerin and alcohol.

B.

Carmine	10 grains.
Liq. ammonia	20 minims.
Distilled water	30 minims.

Dissolve the carmine in the ammonia, in a test tube, with the aid of heat if necessary, and add the water. Mix A and B together and filter.

Place the section in the green stain for five to ten minutes. Wash well in distilled water. Place in carmine stain for ten to fifteen minutes, wash in methylated spirit, in which the section must remain for at least ten minutes. Clear in clove oil and mount in C balsam.

Mounting Sections in Glycerin Jelly.—Place the section in distilled water and soak until all trace of alcohol is removed. Warm the jelly and place a few drops on the center of a clear slide, and put the section in it. Clean a cover glass and apply it in the same way as directed for balsam. Allow the slide to cool, and then the exuded jelly may be scraped away with a penknife and the slide washed with water. Dry well with a soft rag and apply a coat of gold size, and when this has dried, add another of asphalt.—*Pharm. Journ.*

ALUMINUM BRONZE AND BRASS AS A SUITABLE MATERIAL FOR PROPELLERS.*

Now that a determined public effort is being made on this side of the Atlantic to create a steel ship building industry, the materials that are demanded for this purpose assume a new interest to the American metallurgist. In the past the uses of metals in this country have been almost inseparably connected with the land, while in England their application to marine purposes has been equal in importance to that on shore. In the future the same should be the case here. This is the reason for bringing a somewhat nautical or rather naval topic before a body whose chief interests are supposed to lie in the mines and the mountains and in the interior of the country.

A modern ship or "ocean greyhound" (like the City of Paris) is a monument of philosophy and human skill In her graceful lines we have, as Ruskin might quaintly say, a "builded geometry," while in her wonderful machinery for motion, offensive and defensive, we have the entablature of the ideas of a million students, who have at one time or another during the course of a hundred years of her evolution contributed their intellectual mites to render her a thing of beauty and of power.

Notwithstanding her present perfection, the modern ship contains room for further improvement. One of the most important things about her is the propeller. This active member is of more consequence than many constructors have realized or been willing to admit. Yet we have the most undoubted evidence that a slight change in the form, in the material of which it is composed, or even in the condition of the surface of the screw, has made most decided changes in the speed of the ship and the size of her coal bill.

With the form of the propeller the writer does not care to deal. That is meant for our mathematical friends, the designers. The question discussed in this paper is solely one of material; on that point there is considerable data at hand of value and interest.

Like the form of the screw, the material of which it has been composed has been frequently changed. In the beginning it was made of cast iron; succeeding this came the famous *gun* metal or *tin* bronze—in England a composition of copper 86 per cent. to 88 per cent., and from 2 per cent. to 5 per cent. of zinc, and from 8 per cent. to 12 per cent. of tin, while the American standard gun bronze is composed of tin 10 per cent., zinc 2 per cent., and copper 88 per cent.

Following these materials came forged steel blades and phosphor bronze, a new form of gun bronze with a small amount of phosphorus added to flux it and harden it; succeeding the two last simultaneously occurred the use of propellers of mild steel cast in sand and manganese bronze so called, but in reality a Muntz metal, with a composition of from 40 per cent. to 45 per cent. zinc and from 60 per cent. to 55 per cent. of copper, with about as much zinc as would burn off in the melting, replaced with a small percentage of ferro manganese.

Following these came wheels made from Dick's delta metal, a metal similar to manganese bronze, but with iron used instead of ferro-manganese. And last on the list appear Cowles aluminum bronze and aluminum brass. The materials from which propellers are made stand therefore in the following chronological order of their first use:

1. Cast iron.
2. Gun bronze.
3. Forged steel.
4. Phosphor bronze.
5. Manganese bronze.
6. Delta metal.
7. Aluminum bronze.
8. Aluminum brass.

Cast iron upon experience was proved too weak and corrodible for use in fast ships, and it has largely fallen into disuse on sea-going vessels of the better class, although it is still universally used by the craft of the great lakes. Its weakness is such that blades of it had been known to have been whipped off from large wheels in heavy seas by the racing of the engines. So subject is it to corrosion by salt water that Mr. W. C. Wallace stated before the Institution of Naval Architects of England that its average life is but five or six years. Yet it is agreed by eminent English authorities that cast iron resists corrosion better than steel. Another and still worse characteristic of cast iron is utter lack of ductility and inability to withstand a shock when used in thin masses.

Gun bronze upon being substituted for cast iron successfully overcame the objection raised on account of the corrosion of wheels. But it was found that this same obstacle came up in a new shape, that the bronze wheel when operated on a steel or iron ship constituted a galvanic couple, the ship being one pole, the wheel the other, and that the action set up resulted in a serious pitting and corrosion of the iron plates in the stern of the ship. This new difficulty was happily overcome by the attachment of plates of zinc around the inside of the aperture in which the propeller works. The zinc forming a new couple with the bronze, relieved the iron from the pitting action.

Another marked improvement made in substituting gun bronze for cast iron was in the matter of speed. It was found and clearly proved that the same ship with the same size and shaped screw in both cases would make greater speed on less coal with a bronze screw than with one of iron. The causes were plainly discernible why this should be so; the bronze screw would hold a finer edge in use than the iron, which would constantly corrode away, leaving it a dull instrument, which could only be driven at a great waste of power and money. The bronze wheel would also keep a smoother surface by reason of its non-corrodibility also, and by thus saving friction make the increase of speed and economy.

Had the world been content with the slow-going, low-powered ships of fifteen or twenty years ago, there would not have been much reason to ask for anything better than the old gun metal. In its time and place it did good work.

The tensile strength of gun bronze varies from six to ten tons in actual practice. The writer has cut bars from bits of old wheels furnished by our Navy Department, and the best results obtained from these were from five to seven tons tensile strength, yet at the same time he has seen specially prepared cast bars run as high as 25 tons in tensile strength and with 20 per cent. of ductility.

English authorities claim for it 12 to 16 tons tensile strength and from 1 to 5 per cent. of ductility. These results were probably on small bars, on bars 2 in. in diameter and 15 in. between marks. Chief Engineer Harris, of the U. S. Navy, obtained a strength of but 10 to 12 tons per square inch and three and one-third per cent. ductility. To secure greater strength and stiffness the English shipbuilders next tried forged steel and cast steel wheels, and many wheels of this nature are now in use. In them there is plenty of strength and toughness, but the question of the corrosion reappears, and it is a most serious one.

Mr. W. C. Wallace, a naval architect of high repute in Scotland, who collected a vast amount of valuable data on this subject, states that he has come across many vessels trading in different parts of the world whose steel wheels had not lasted more than three years. His testimony as to the very rapid corrosion of steel is sustained by Admiral Colomb, of the English navy, by the experience of the firm of Messrs. Jessop & Co., as related by their Mr. Hall before the Institution of Naval Officers, and Mr. G. W. Manuel, superintendent engineer of the P. & O. Steam Navigation Company, and other distinguished engineers.

Phosphor bronze was found to be little if any better than the gun bronze in the matter of strength, although, of course, sufficiently non-corrodible. Its much higher price precluded an extensive use of it for propellers.

Delta metal, like phosphor bronze and manganese bronze, came into a very limited use in the effort to secure a strong and yet non-corrodible material. It is not made in America, and little authentic information is known of the success attained with it, although the proprietor, Mr. Dick, has informed me that large propellers have been successfully cast from it. When properly made, it is stronger than gun bronze or manganese bronze. It has about the same composition as the sterro metal of Gen. Uchatius, of Austria.

Manganese bronze, so called, is in reality a manganese brass, for zinc instead of tin is the chief element added to the copper. What its real strength and ductility is few, if any, people know. Mr. P. M. Parsons, the proprietor of this brand of metal, claimed for it in *London Engineering* of April 20, 1888, in a controversy with the writer, a tensile strength of from 24 to 28 tons on small bars when cast in sand. He also claimed for it a transverse strength of two long tons on a bar 1 in. by 1 in. by 12 in., and I do not doubt but that such results have been attained by him.

Mr. W. C. Wallace states that brass founders of high repute in England will only admit that manganese bronze has from 12 to 17 tons tensile strength and 28 cwt. transverse strength. Mr. Horace See, recently head designer for the Messrs. Cramp, stated lately in New York *Times* that he had privately tested the metal used in the U. S. ship Yorktown, and that it developed a registered tensile strength of 45,000 pounds per square inch, and from 6 to 12½ per cent. elongation. He did not state the dimensions of the bars nor how the same were made—two all-important considerations.

The Messrs. Cramp & Co. claim for the metal a strength of from 45,000 to 60,000 pounds, and I do not doubt but that such results have occasionally been attained on very small bars cast under the most favorable conditions, precisely as similar and equally high results have been obtained on the old gun bronze. The writer's experience with it in the testing machine is that it is a material about one-quarter stronger than the old gun bronze, and I should be much surprised to see it exhibit a greater tensile strength than 30,000 pounds on a bar 2 in. in diameter and 15 in. between marks. So far as non-corrodibility and casting qualities are concerned manganese bronze is all that the gun bronze was. It is extensively and successfully used.

Aluminum bronze: this material is by long odds the strongest of all the copper alloys. A small bar of it cast in sand broke in the testing machine of the Leeds Forge Co., at Leeds, Eng., in the presence of Mr. Sampson Fox, the inventor of the corrugated boiler tube, at the unheard of load for a copper alloy of 130,000 pounds per square inch, and with about ½ of 1 per cent. elongation in one inch. The bronze in question was made at Lockport, N. Y., in the Cowles Electric Furnace, from corundum, and had approximately 9¾ per cent. of aluminum, 1¼ per cent. of silicon, ½ per cent. iron, and 88½ per cent. of copper in its composition. It is what is known as the A 1 grade of bronze.

Many hundreds of tests on this grade of metal on small bars up to three-fourths of an inch in diameter prove its tensile strength to be over 100,000 pounds on bars of that size, while its transverse strength on one test ran as high as 9,500 pounds on a bar 1 in. by 1 in. by 12 in. Its elastic limit is proportionately high, and its hardness far above all other alloys. Its corrodibility is far less in salt water than manganese or gun bronze.

To those designers who desire a material that will stay in place when the engines are exerting their greatest power, the stiffness and high elastic limit of A 1 bronze render it an ideal metal. That it is a short metal so far as ductility is concerned should not weigh against it, for it is in no sense a brittle metal. Even the hardest and strongest pieces of it will bend a trifle, and its resistance to shock is remarkable. But while these are its advantages, like all good things it is not without its imperfections—it has to be properly cast, and by people who are familiar with it, to obtain good results.

To founders who do not understand it, no more refractory metal can be given. Still, there is nothing in the handling of this material more difficult to overcome than what has been done in the working of steel in countless instances. Its price alone is the one great obstacle to its introduction into propellers generally. This is approximately $700 per ton for the ingot metal alone.

Aluminum brass will be found a material that has the maximum of good qualities sought for by the propeller makers at the minimum cost. This alloy is produced by taking equal weights of A 1 aluminum bronze (that made from corundum is the best for this purpose, the silicon and iron present being necessary elements if it is desired to obtain the highest possible strength), copper, and zinc, and fusing the same together. The copper and bronze are first thoroughly melted and mixed and the zinc finally added. The material is left in the furnace until small test bars are taken from it and broken. When these bars show a tensile strength of 80,000 pounds or over, with 2 per cent. or 3 per cent. ductility, the metal is ready to be poured. Tests upon this bronze on small bars have at times shown as high as 100,000 pounds tensile strength. Three of these which are attached to a large casting made by the Brush Electric Co., at Cleveland, for the hub of the Colossus dynamo in the Cowles works at Lockport, exhibited a tensile strength from 93,000 to 96 000 pounds, and 2½ per cent. to 7 per cent. elongation. A bar of it 2 in. in diameter and 15 in. long was broken at 82,000 pounds on the Watertown machine, by Chief Engineer Harris, U.S.N., whose results appear in a letter appended to this paper along with other tests of these alloys. Three tests of this No 2 brass in England on sand castings gave equally high results. A bar 1 in. by 6 in. broke at 76,187 pounds, elongation 1½ per cent. Another bar 2 in. by 12 in. broke with a load of 72,912 pounds per square inch and 1 per cent. elongation. The last bar was 3 in. in diameter and 18 in. long between marks. It broke at 66,752 pounds and a slight elongation. These three tests were all made at the proving house of the Lloyd's, near Netherton, and in conjunction with the American tests are now most conclusive. The brass was made at the Cowles Electric Smelting plant at Milton, near Stoke on Trent. The three inch bar above referred to was cast attached to a large propeller blade. Its elastic limit is undoubtedly almost as high as A 1 aluminum bronze, and its real strength must certainly be fully twice or three times that of manganese bronze, while its casting qualities are all that can be desired. The screw of the U. S. gun boat Petrel is cast from this brass, mixed with a trifle less zinc in order to increase its ductility. Its cost is about the same as that of other alloys. Our No. 1 aluminum brass has less tensile strength, but 15 to 20 per cent. ductility.

In reviewing the various alloys and metals used in screws I have but in one instance mentioned the price of the material, for the reason that the cost of the iron and steel wheels are patent to us all, and that with but one exception the prices of the alloys are so nearly the

* Read by Eugene H. Cowles at meeting of the American Institute Mining Engineers, Feb. 21, 1890, Washington, D. C.

same that quality should alone be considered in selecting the proper one for this purpose.

In passing upon the various materials above cited a rather confused idea of the strength of the several alloys may appear to prevail. This is due to the fact that we have not to-day in this country or in England any official standard by which to judge of the physical characteristics of cast metals. The Harris test bar is 22 in. long, 2½ in. in diameter at the head and 2 in. in diameter in the shank, and 15 in. between elongation marks.

Cowles aluminum bronze and brass, the United States government gun bronze, and the "deoxidized" bronze from the Bridgeport and Cowles manganese bronze have thus far been tested at Watertown on bars of the above dimensions. At the first glance this would seem to be all that is desired, but there are two other requirements that are absolutely necessary before we can secure a fair comparison of different materials; one is a statement as to whether the same was cast in dry or green sand, or in a chill; the other inquiry is whether it was cast attached to a larger casting or cast by itself.

It has been the experience at the Cowles Lockport works, where all of the non-ferrous alloys have been tested at great expense and labor, that as a rule the smaller the bar the higher the result, no matter what alloy is under consideration, unless it is perhaps the aluminum brass. Tin bronze and manganese bronze show this to be so, as much as aluminum bronze. It is also true of the ordinary brasses. It has also been found to be true that chill castings give higher results than sand castings, and that bars cast by themselves purposely for testing almost invariably run higher than those of the same material cast attached to castings. It is also a fact that bars cut out from castings are generally weaker than bars cast alone. From the above it will be seen that it is of the utmost importance that all test bars of cast metals, if a fair comparison is to be had, must be made under identically the same conditions in the foundry. Where the material is supposed to be the same, or approximately so, a complete analysis of the bars should be made.

To sum up, the advantages that we claim for aluminum brass are as follows: Its enormous transverse strength permits far thinner blades being made of it than can be made of any other alloy.

Its greater hardness renders it possible for it to take and to hold a sharper edge longer than other alloys. It is now the practice of the best constructors to sharpen the edges of their wheels until they are almost like a knife.

Its unequaled elastic limit keeps the wheel in perfect form and true to its mathematical design under far heavier strains than can be withstood by any metal except steel.

Its higher resistance to corrosion preserves the brightness and smoothness of the face of the blades, and thus reduces friction more than other alloys.

Its greater freedom from galvanic action reduces the amount of zinc plate used and renders it less expensive to operate than any other alloy. This cost of zinc plates is an item of expense that amounts to quite an annual percentage on the cost of any bronze propeller.

In short, it is possible to make the lightest, strongest and most non-corrodible propeller yet known from aluminum bronze or brass, and the 25 or 30 knot vessels of the near future will only be a possibility by reason of its use.

U. S. Navy Department, Bureau of Steam Engineering,
Washington, December 20, 1887.

Sir: In obedience to orders of the 22d ult., I have visited Watertown, Mass., and Lockport, N. Y., to witness experiments at the former place upon specimens of aluminum bronze and brass, submitted for tensile tests by the Cowles Electric Smelting and Aluminum Company, of Lockport, N. Y., which place I visited after the tests at Watertown were completed.

In competition with the bronze specimens furnished by the above company, the bureau directed that six specimens of the tin bronze, usually used for propeller castings in the United States naval service, be tested under like conditions.

All specimens tested were 15 in. in length between reference marks, and if finished all over were 1⅞ in. in diameter; those which were left as taken from the sand were slightly in excess of this diameter, 1·93 in. being the greatest diameter recorded.

A tabulated statement of the results of the tests is appended to this report.

All of the above aluminum bronzes can be worked hot or cold, but no experiments have been made to my knowledge to determine their strengths after such working.

It makes sound and sharp castings. Its greater tensile strength allows the use of thinner and consequently lighter blades for propellers, and its great ductility allows of its being bent to nearly a right angle without showing cracks or flaws. I have no knowledge of any alloy of copper which, as a casting, combines the qualities which this material possesses.

Very respectfully,
WM. H. HARRIS, Chief Engineer, U. S. N.

The following table and remarks cover the details of the tests made by Engineer Harris, and are from the Proceedings of the United States Naval Institute:

HARRIS' TESTS OF ALUMINUM ALLOYS.

Marks	1 C	7 C	9 C	10 C	11 C
Length, inches	15	15	15	15	15
Diameter, inches	1·87	1·87	1·87	1·87	1·87
Area, inches	2·76	2·76	2·76	2·76	2·76
Diam. at fracture inches	1·56	1·8	1·66	1·82	1·78
Ten. s. per sq. in., lb.	60·700	66·000	67·600	72·830	82·200
Elastic limit per sq. in., lb.	18·000	27 000	24·000	33·000	60 to 75·000
Elongation p. ct.	23·2	3·8	13·0	2·40	2·33
Reducti'n of area per cent.	30·7	7·8	21 62	5·78	9·88

HARRIS' TESTS OF ALUMINUM ALLOYS.

Marks	11 D	13 C	9 D	10 D	13 D
Length, inches	15	15	15	15	15
Diameter, inches	1·9	1·87	1 9	1·87	1 87
Area, inches	2·84	2·76	2·84	2·76	2 76
Diameter at fracture, inches	1·86	1·64	1·75	1·86	1 73
Ten. s. per sq. in., lb.	70·400	59·100	53·000	69·930	46·550
Elastic limit per sq. in., lb	55·000	19·000	19 000	33·000	17·000
Elongation, per cent.	0·4	15·1	6·2	1·33	7·8
Reduction of area per cent.	4 33	23·59	15·5	3 30	19·19

HARRIS' TESTS OF NAVY GUN BRONZE.

Marks	1	2	3	4	5
Length, inches	15	15	15	15	15
Diameter, inches	1·87	1·87	1·87	1·88	1·88
Area, inches	2·76	2·76	2·76	2·77	2·77
Diameter at fracture, inches	1·83	1 81	1·77	1·78	1 82
Ten. s. per sq. in., lb.	18 000	24·590	22 500	23 000	20·570
Elastic limit per sq. in., lb	10·000	11·000	11·000	13·000	13·000
Elongation, per cent.	2·5	8·2	5·8	4·0	2·33
Reduction of area per cent	4·7	6 8	10·89	10·36	6·3

ALUMINUM BRONZE OR BRASS.

Mark or number.	Approximate composition of the above.			
1 C	Cu 91 5/8	Al 6½	Si 1·75%	Te ¼%
7 C	Cu 88½	Al 9½	Si 1·66	Te ½%
9 C	Cu 91·5	Al 6½	Si 1·75	Te ⅜%
10 C	Cu 90	Al 9	Si 1	
11 C	Cu 63	Zn 33·33	Al 3½	Si 0·33
11 D	Cu 63	Zn 33·33	Al 3·33	Si 0·33
13 C	Cu 91⅛	Al 6½	Si 1¾	Te ⅛%
9 D	Cu 93	Al 6½	Si 1½%	
10 D	Cu 89¾	Al 9⅛	Si 1·66	Te ⅛%
13 D	Cu 92	Al 6·5	Si 0·5	

The Cowles aluminum brass is a patented composition.

NAVY YARD BRONZE.

Mark or No.	Approximate composition.		
1	Cu 88	Sn 10	Zn 2
2	"	"	"
3	"	"	"
4	"	"	"
5	"	"	"
6	"	"	"

The following table shows the results of tests on the hardness of the large bars:

ALUMINUM BRONZE OR BRASS.

Mark.	Hardness of head.	Hardness of stem.
1 C	9·39	13·85
7 C	14·12	14·26
9 C	11·18	13·59
11 C	14·69	10·6
10 D	17·08	16·7

NAVY YARD BRONZE.

No. 1	3·33	3 33
No. 5	3 67	6·56

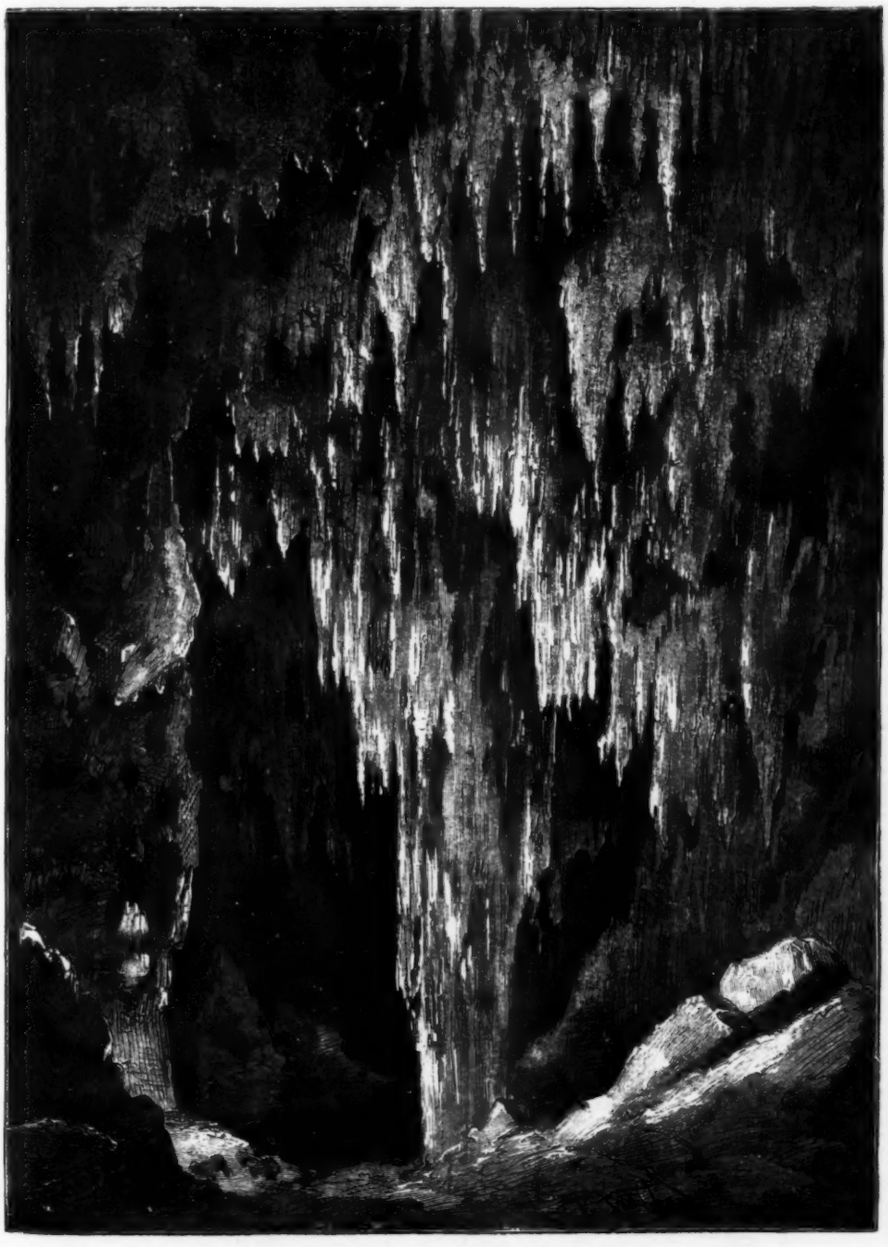
The bars furnished by the government and marked "navy bronze" were carefully cast at the New York Navy Yard, under the inspection of an officer detailed for that purpose, and were exceedingly fine castings. You will notice that they are of the composition of ordinary gun bronze.

TESTS OF ALUMINUM ALLOYS.

Two more bars cast in green sand, of the same grade as above, of aluminum bronze, were officially tested, and resulted as follows:

TEST AT WASHINGTON NAVY YARD, MADE FOR LIEUTENANT MARTIN E. HALL, U. S. N., OF ALUMINUM BRONZE, FURNISHED BY THE COWLES ELECTRIC SMELTING AND ALUMINUM COMPANY.

Grade of specimen Al.	Dimensions of specimens. Length.	Dimensions of specimens. Diameter.	Weight applied.	Elastic limit per sq. inch on original cross section.	Weight per sq. inch on original cross section.	Elongation.	Reduction of area.
	in.	in.	lb.	lb.	lb.	p. c.	p. c.
No. 1	2·0	0·500	22,485		144,514	0·45	0·00
No. 3	2·0	0·501	21,650	79,894	100,828	0·08	2·00



DER REICHSPALAST (THE IMPERIAL PALACE).

CAST IRON AND ITS TREATMENT FOR ARTISTIC PURPOSES.*

By W. R. LETHABY.

"From that one surrender of its integrity, from that one endeavor to assume the semblance of what it was not, arose the multitudinous forms of disease and decrepitude."—*The Lamp of Truth.*

"The value of every work of art is exactly in the ratio of the quantity of humanity which has been put into it, and legibly expressed upon it forever."—*The Stones of Venice.*

THE word "art" embraces in its wide reach everything added to the work of man for order's sake, for fitness, and for beauty; from high invention, passion, and stimulating thought to the decencies of mere custom and habit. It would seem that man's labor, and indeed his life, must be seasoned with this salt. We cannot imagine a shirt sewn, a doorstep whitened, or a table laid, without some care and contrivance for enjoyment over and above the mere needs and necessities of the moment; and every calling of any ancestry at all, shaped by use and observance, from war to agriculture, is made sightly and beautiful by the ordinances and traditions of it, so that they are unthinkable without art. Truly, as Mr. Ruskin says, "Life without art is brutality;" for mere labor is chaotic and destructive of manliness: without this tribute to Nature's order and man's own self-respect, it numbs and atrophies the sensibilities. Art is a debt we may say we owe to material, the seal that alone makes a thing worthy to exist.

Too many of our industries have fallen out of the categories of art into mere "production," as it is called, wanton and careless of other ends than immediate profit.

Now, this art of iron founding has interested me because, on this hand, it is one of our vastest resources, national in its importance: and on the other hand, degraded and scorned, it has become a commonplace of cant to decry it, until, for the most part, it has become worthy of the disdain. But art is universal: to give up one corner of the field is to destroy the fair harvest; it it is which plaits the straw finial on the wheat stacks of the homesteads as well as points the proudest steeple. All materials are alike, if not equally, vehicles for its expression; each one of which can give us something simple and alone, something without which the world suffers lack.

In the notes that follow I do not propose to speak of the metallurgy or manufacture of iron, in both of which I am sufficiently ignorant. I want, rather, by an examination of specimens which I think beautiful or suggestive, to arrive at what—to borrow Mr. Pater's word—we will call an "appreciation" of the metal, and certain methods of manipulation. For me, therefore, the primitive apparatus of the East for obtaining iron—a few stones and clay for furnace, a goat skin and bamboo for bellows, and charcoal for fuel—producing the wonderful watered blades of swords or daggers, inlaid with purple gems like the stain of a death blow: or those in which rubies run like red drops of blood along a groove to the point. Such apparatus is more for my immediate purpose than the towns of fire and sulphur which produce—what?

The easy contempt we feel for iron is the direct result of our treatment of it for gain and not for true service. Yet sentimentally—and all art has to find out the intrinsic sentiment of phenomena and so interpret them in an exalted form—there is a certain mysterious appeal in iron only surpassed probably by the gold of the poets with its red bloom, and so pure as to be "soft as wax;" barbarous, occult, and fateful.

Iron, on the other hand, stands for strength, simplicity, even severity, and, on its sinister side, for cruelty and terror. In the old apportionment of the seven metals to the seven planets iron belongs to Mars, as gold to the sun and silver to the moon; and Chaucer rears his temple of Mars on iron pillars of the diameter of a barrel and polished.

> "Every pillar the temple to sustain
> Was ton-great, of iron bright and shene.
> There saw I first the dark imagining
> Of felonie, and all the compassing."

Dante, too, builds of it, . . . "the moats profound. That circumvallate that disconsolate city." We are not conscious of any mean reflection or association, but rather an exaltation of the imagination, when, in the curious myth of Mahomet's coffin, we are told that it was of iron, sustained in the air by the equal attraction of the walls, ceiling, and floor, which were of loadstone; or in another Eastern tale, "The City of Brass," where it says that an inscribed tablet of iron of China was suspended in front of the "Terrible Tomb;" we feel that bronze or even gold would be an anti-climax. In the image interpreted by Daniel, iron stands for power, "Strong as iron: forasmuch as iron breaketh in pieces and subdueth all things," and "wherein (as says the Koran) is mighty strength for war." To come to actual instances. When in the fourth century a great Indian raja set up the pillar of Delhi at the true center of the round world, to commemorate, as the inscription reads, having "obtained with his own arm an undivided sovereignty over the earth," the great shaft of iron was made which, still undecayed, forms one of the oldest of Indian records. The iron crown of Lombardy, or the cross of Germany, are further instances in which the mere name of the metal lends a mysterious and moving import of invincible sternness.

The highest art is to concentrate the powers for one premeditated appeal to stimulate the imagination, and for this the quality of inherent sentiment of the material is not the least of the formative factors; as the Egyptians knew well when they selected black basalt for their statues; and the Hindoos, again, when in some of their temples they used great beams of iron, not as mean, but precious things. And Pliny, when he tells us of a certain statue of cast iron, says that it was chosen as appropriate to the subject—a Hercules.

As our sensibility widens and deepens, we shall find that not a given material, the whitest marble or greenest bronze, is necessarily artistic, but the intellectual or intuitive grasp by which material and motive, texture and technique, are made to co-ordinate in one balanced and adequate result. And thus stern iron might offer in the hands of a master a material of great value in serious and commanding work; indeed, on the plane of the highest sculpture, we can only think one man's work into iron, and that man the greatest artist of them all. We might, perhaps, be allowed to recommend to the rising new school of English sculpture sometimes to think away from the, perhaps, petty prettiness of bronze, to *think* sometimes in iron.

Having once made this claim for iron to a place in serious art, my actual examples will be of much lower range and humbler intention. Waiving this possibility of the highest appeal, and selecting iron because of its commonness and powers of resistance, it has been treated as an art "not too great and good for human nature's daily food," but still an art real of its kind. By a careful selection of the forms and treatment suited to the structure and texture of the material, and its application to commonplace needs, the charms

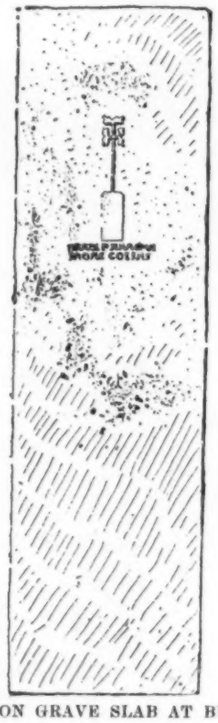


FIG. 1.—IRON GRAVE SLAB AT BURWASH.

of fitness and honest simplicity have been given to it, and by accepting the comparative valuelessness of the metal, it has been used as the vehicle for slight thoughts and slighter execution. It should not be without result that by far the greatest of our designer sculptors, the late Alfred Stevens, worked long and thoroughly as a modeler for cast iron, from no choice of his own, it may be, nor choice, probably, of subject; and yet by far the most popular work of modern sculpture, the little lions on the outer rail of the British Museum, of which so many other artists are glad to keep casts by them as examples of breadth and style, are only cast iron. That they should be painted such a repellent color is but an accident of their fate—the irony of fate.

The torch holders on the top of the same screen, with reliefs of heads surrounding the bowls, are also his. Table supports, stoves, and grates also occupied his care. Some of them are described in Mr. Armstrong's book, and a specimen may be seen in Chelsea town hall.

At South Kensington, in the buildings on the west side of the road, there are two well modeled dogs, modern French work, bronzed on the surface; and in the museum of the School of Mines, in Jermyn Street, there are several works, statues, and other dogs, after the antique as well as modern work; one of these is especially interesting, for it is shown as it came from the mould, with seams, jets, and supports not cut away, nor any surface chasings. At a doorway at the west end of Conduit Street stand another pair of dogs in iron. Many of the firebacks which we shall notice later are low-relief sculptures of considerable merit, especially that at Bruges, which has two nude figures some 3 feet 6 inches high, as supporters to a shield.

The invention of casting in iron seems to have been made very early. Pausanius says of Theodorus of Samos—a sort of antique Cellini to whom they appear to have ascribed most wonderful works in metal, and who is supposed to have lived in the sixth century B. C.—that he cast figures of iron; and both this writer and Pliny mention other statues of this material. An Etruscan statue and a head of Roman work are said still to exist. England, we know, was extensively worked for iron by the Romans, and vast cinder beds have been found near Buxted, in Sussex, with scraps of pottery and coins of Nero, Vespasian, and Diocletian. Iron rings formed the currency of the natives when Cæsar "came, and saw, and conquered."

There is, however, I believe, no evidence to show that casting iron was practiced here before the middle ages, nor at what time it was then introduced. M. Viollet-le-Duc, who more than any one knew the history of mediæval crafts in France, does not mind supposing that it was known there in the 13th century, to which date he attributes a fragment at St. Denis. In the 14th century cast iron artillery was probably founded all over Western Europe, and it is likely enough that this may have introduced the furnaces into Sussex, in spite of the couplet which says:

> "Master Huggett and his man John
> They did cast the first Cannon."

Magnificent bronze sculptures we know were cast here in the 13th century by Torelli, the artist of the lovely Queen Eleanor's tomb at Westminster Abbey.

If so introduced with artillery, the founders soon cast other objects. There are in the churches of the counties of Sussex and Kent a large number of grave slabs, the earliest of those known being at Burwash; this is shown in the figure. From the form of the cross and the Lombardic lettering it is almost certainly a work of the 14th century. Mr. Lower, the writer of an able paper, from the historical side, in the second volume of the Sussex Transactions, gives this date; he says the inscription is a good deal injured, but reads—

ORATE. P. ANNEMA
JHONE COLINS

The placing of this on the plain field of the slab is full of art, and characteristic of early taste.

At Crowhurst is a sepulchral slab inscribed to Anne Forster; it bears figures—an effigy of herself, and on one side two boys, on the other two girls kneeling, below are small shields of arms, a lion rampant, and a chevron with three greyhounds; it is surrounded by borders of running grapevine, certainly good Gothic work, and earlier than the date 1591, which the slab bears. These patterns were kept in the shop and frequently reused. The inscription in nicely formed and spaced letters reads—

HER LIETH ANE FORST
R DAUGHTER AND
HEYR TO THOMAS
GAYNSFORD ESQUIER
DECEASED XVIII OF
IANUARI 1591 LEAVYING
BEHIND HER II SONES
AND V DAUGHTERS

not forgetting to turn a few letters upside down and other way about, which was most carefully seen to in old inscriptions, so that those who ran should not read. There appear to have been several repetitions made of parts of this slab for firebacks. Mr. Longden has one of these, of which a drawing from a rubbing is on the wall. In the meanders of vine the pattern is formed by repeats of one small portion which was either impressed separately into the flat field of the sand mould or several casts of it were attached to the foundation board. I also show a full sized sketch of this ornament, which may be compared with another tendril of vine, also of 15th century work; Gothic, if late, of a very good style, reused on a fireback of later date at Buxted.

There are a great number of these slabs; examples are at East Grinstead, 1570, and Witham, 1582, also several at Wadhurst, one with coat of arms, crest, and inscription dated 1648; another has six shields charged with three stars and initials "W. B.," and a late slab (1752) bears in brass letters on an iron plate the epitaph of "John Legas, gentleman, who, by his industry and intelligence in the iron works of this country, acquired a handsome fortune with great credit and reputation," etc., which is much more modern than the early Gothic sentiment, "Pray for the soul of Jhone Colins," who has also been identified with a family of iron founders. In Frant, near Tunbridge, there are also several slabs with shields of arms. Later examples again may be found at Streat, and sometimes an iron plate of inscription is inserted in an outdoor tomb, as at Alfriston, or a low cross is entirely iron as at Croydon, and all of them have the charm of an endeavor, simple and unaffected, which, with a child-like directness, knew nothing of art but wrought it, talked nothing of beauty but thought it.

In the great open fireplaces where logs burnt on the hearth of hall and kitchen, cast iron slabs called firebacks were put against the wall behind the fire. They are found alike in France, in the Low Countries, and in England, and invariably charged with some device, arms, inscription, badge, or a scene scriptural or classic, an allegory or a fable, something to suggest a thought, as the pattern adorned the opening in summer or burnt red hot behind the winter fire; all these things were books.

One of the largest and best in the modeling is that at Bruges before mentioned, with figures of nude savages, gentle as Rousseau's natural man, supporting a shield. They are too high in relief, but evidently the work of a very good sculptor, and dated 1565. I have on the table a slight sketch of the Eve. The rest of the fireplace is entirely covered with cast iron plate, diapered over with a pattern of quatrefoils and shields. Mr. Longden has two French figure panels, dated 1518, which probably formed the cheeks to such a metal plated fireplace; and Mr. Blomfield in his interesting papers in the "Portfolio" for 1886, mentions firebacks that used to exist at Linham, Kent, "covered with men and great roses, and extending across the entire chimney back." The great roses remind us of the plaster work, painted in natural colors, of the inn kitchen in Mr. Morris's "Dream of John Ball." A suggestion of the sweeter things of nature is alike welcome in cast iron or in cast plaster.

FIG. 2.—DESIGN IN IRON FIREBACK AT BUXTED.

* A paper recently read before the Society of Arts, London. From the *Journal* of the Society.

The earliest of the south county backs I know of belongs to Mr. J. C. Horsley, R.A., at Cranbrook, and is certainly good Gothic work in flat tracery of a sort of butter print style, and the sacred monogram, X. P. C. There is a drawing of this example the full size on the wall.

In another place I have spoken of the necessity of the relief being flat, and modeled but slightly, not rigidly carved with sharp definition. This last example is, however, almost certainly from a carved original, and Mr. Blomfield mentions actual patterns of wood in existence; but the dull unobtrusive relief is not less successful for being carved. They knew what they were seeking for in the finished work, and found it, whereas our patterns are for the most part thought out as carved wood and cast. The back in the farmhouse at Buxted, which has the early vine pattern, is of Queen Elizabeth's time. The decoration is amusingly haphazard; first, the Gothic meander impressed along the top, and in the center the crowned rose of the Queen, and the letters, "E. R.," all in matrix instead of relief, and the letters wrong side foremost; a plaster mould apparently, instead of an object, has been impressed into the sand. There are two other roses impressed in the same way, and two shields the right way up.

This casual look of old work is not so accidental as we may be likely to think, for in the carved work of the same time we find letters reversed, or top downward. It is clear they looked on letters as designs and cared little for the laws of Medes and Persians or those who dare neither play nor smile over their work. A dreary dead level of dull accuracy is nearly the chief incubus that paralyzes our present crafts, until art becomes but another weariness.

The ornament, whatever it may be, in true Gothic is always some suggestion of life and growth, roses or vine. This, not buttresses, cusps, nor tracery, is the living principle of pre-Raphaelite art, and the reverse of this, not symmetry, nor simple mouldings, nor large forms, is the essential impurity of the corrupt Renaissance. Since Della Robbia modeled his wreaths of lemons, apples, and fir cones, hardly a single fresh thought, the sight and scent of flowers, or spring of living foliage had inspired pattern decoration until Mr. Wm. Morris, whose work it would be difficult to speak of in measured words, so stimulating it is in adapting from nature the evergreen source of all new life in art. A color pattern of his is not a mere reshuffling of the beggarly elements of design, but an impression of how bright stars of jessamine twinkle on a twilight of green. As Mr. Blackmore's John Ridd says, "The more a man can fling his arms (so to say) round Nature's neck, the more he can upon her bosom like an infant lie and suck, the more that man shall earn the trust and love of all his fellow men."

The later firebacks are very numerous, although for the most part now in "collections" instead of adorning the cottage hearth or the hall for which they were specially made, for hardly any exact duplicates occur, and in very many instances the arms or an inscription identify the former owner's family. A back at Misfield, in Sussex, is a charming design; at the top in a little gable the crowned badge and supporters of Elizabeth and five tiny shields, with an inscription

THOMAS UNSTED ISFIELD AND
DINAS HIS WIF: ANO DOMINI. 1582.

all mixed up together in amusing confusion of wavering lines of letters. Or another

THES IS FOR JAMES HIDE AND ION HIS WIF
1582.

The coats of arms are large or small, with or without supporters, or a number of small shields fill up the whole space; many have the royal arms, others horsed warriors galloping in attitudes expressive of a consciousness of the converging gaze of nations.

The Scripture scenes are telling groups of Abraham and Isaac, David and Goliath, the Queen of Sheba astonished at the splendor of Solomon, the Annunciation, and the Woman of Samaria; or Michael casting Satan out.

Classic story has Venus and Adonis, Pallas, Juno and Venus, Hercules and the Lion, Neptune, Apollo, Vulcan in his smithy, and Juno in a car drawn by peacocks, or there are fables of Æsop—The Thief and the Dog, or Fox and Crane. There are Seasons and the Four Quarters of the World, Allegories of Time, Peace, Fame in a Chariot and the necessary trumpet, vases of flowers, trophies, a Parrot in a Ring, Chariot driving over a Bridge, or Early Bird getting the Worm.

There are many devices that refer to the Stuart Kings, Charles I. on a Horse, and letters "C. R." An anchor crowned, and the same initials; or an oak tree lettered "Royal Oak" and "C. R." again. Good examples of royal arms are at Hampton Court.

The most beautiful example known to me is one of which a photograph is kindly lent me by Mr. Longden. A Roman soldier with a long spear, in three-quarter back view, within a margin line which sprouts out flowers and a flowery top and borders; it is a work of very considerable skill, sense of decorative spacing, and a touch unconscious and unaffected. The date, 1746, of this example would probably be later than the original model. Another of "Lord Fairfax" riding fills the field well; the horse, the attitude, and the flying drapery remind one of the old broad seals on which the design is evidently founded. Another, of which I have a sketch, has for center a large apple tree, with a cavalier and a lady on opposite sides. She offers him a flower—a new Eve.

A beautifully designed example, with many others, is in the possession of Mr. Elsley. Within a wattled sheepfold sits the genius of a country, on a staff she upholds the cap of liberty, and before her a crowned lion strikes a most ramping attitude with sword and thunderbolts; it is lettered "Pro Patria." Others have a single figure of a girl with a bird on finger, or pouring wine, or a vase of flowers is made to fill the ground, with great skill in distribution of the forms. In the museum at Lewes, a salamander basks in his native element with much complacency. The second figure of the date of this one, 1550, is certainly "forged" in both senses of the word.

The actual achievement in the poorest of these firebacks is low enough. Some are, in fact, almost grotesque, but yet they all have that fresh touch of a real motive, a direct reference to some expressive gesture or pleasant object; all treated with great simplicity, and that instinct for balance and spontaneous fitness and freedom in the ornament, without any forcing the material or obtrusive display which is the mark of the traditional crafts.

The system is, almost without exception, to keep a flat field, which shows in pretty wide spaces all over, and the modeling on this is in low relief—the less the better—evenly balanced and of equal weight throughout, so that the light is distributed in narrow edge lines right over the surface—to sum up in a word, a decorated plate of iron, instead of a cast sculpture of bossy high lights, and the ground lost in the weight of the relief.

Accepting this treatment, the better the sculpture, indeed, the better, but yet it must suggest, not realize, the slightness and vagueness in parts fading to mystery. The best of all reliefs, as Mr. Ruskin so finely says, "are but shadows."

The firedogs or andirons which accompanied the backs on the hearth make a parallel series. De Caumont and Viollet-le-Duc cite examples of late 14th century and early 15th century in France; and a sketch I made in the museum at Angers, of a Gothic example of this date, is on the wall; many of later date still carry on the Gothic forms in England; from an arched base, sometimes cusped, springs a stem, which carries a small shield, a capital, or a head; several examples may be found figured in the articles before quoted. They are interesting historically, but are not, I think, the models we should follow. We have seen enough of the "Gothic revival" in cast iron; what we want is new thought based on practical needs and the Gothic spirit of a search for beauty untrammeled by formulas. Still later examples of the 17th century were figures or "terms," the best designed of which are signed "Carron." I bring here one of these of my own, a

FIG. 3.

FIG. 4.

IRON GRATEBACKS.

small female figure, and show a sketch of a terminal figure of a man which is both larger and better modeled; but even the former, poor example enough as it is in its way, is much better than a far abler sculptor would be likely to give us who did not sympathetically approach the material he was working in, and design within rigid limits; for, first of all, the figure must be just a solid post without weak projections or detail, and in this the old ones, without exception, are successful. Perfectly plain turned vase and baluster forms on a base, or obelisk-like posts on pedestals, were also used, and are probably as appropriate as any. Simplicity alone never fails; it is the charity of design that will cover a multitude of sins. To aspire is well, but to aspire vulgarly and fail weakly is to make art an offense and distaste.

Other objects of the middle ages were vessels. Some years ago I drew one of a pair of large metal holy water basins, like inverted bells, at St. Pierre-sous-Vézelay, in Burgundy, I find that Viollet-le-Duc gives them as cast iron. "Two of these mortars of iron," he says, "have served a long time as benetiers in the church of St. Pierre-sous-Vézelay; perhaps they are there yet; they were of great size, nearly 3 ft. in diameter, and very well cast, with ornaments and ring handles; they probably came from the abbey of Vézelay." He also illustrates another example with lions' heads carrying the rings.

The foundries of Staffordshire also produced small objects of this sort before the time of Elizabeth. "Brewing cisterns, pots, and mortars" are mentioned.

In Sussex the iron trade assumed such large proportions, especially after the introduction of blast furnaces worked by water wheels, in Queen Elizabeth's reign, that the exhaustion of the timber in the supply of charcoal fuel caused much anxiety, and an effort was made to limit the industry. In 1607, an amusing tract argues the question in dialogue, the upholders of the local trade doing so on purely philanthropic grounds. The clearance of the woods was a benefit to mankind, for "people bred among woods are naturally more stubborne and uncivil than in the champion (*sic*) countries." At this time there is stated to have been as many as 140 furnaces in Sussex.

I am not one of those who wish to see in iron a material for a new architecture, as it is called, nor do I wish its extended use; rather inversely, a smaller field, but that field as full of flowers as may be. Mr. Ruskin, with that insight which makes him refuse to talk about the fringe of a subject, saw clearly, when everybody was clapping their hands over the Crystal Palace, that the finding and founding of iron is not one of the radically nobler employments, as stone hewing and setting is, or the felling and framing of timber. I would echo every word he says. But while we use iron in some degree, while we even need iron, while even it may grow into wider necessary use, I want to say let us lend what grace we may to it, so that if obtained with cost, the greatest of all cost, an unkindly labor, it may not be misspent and more than spoilt, used to insult a trained understanding in the brutality of its vulgar insolence. For in all these things it is human life we spend: there is really no other currency, and so comes the reverence any true worker always feels for material.

Cast iron was largely used in the pleasant and refined manner of building, from the end of the 18th century, the typical London house. In the great area from Paddington to Pimlico, and Bloomsbury to Bayswater, there are an infinite number of examples of a quiet and charming taste. Railings, balconies, verandas, with graceful posts and panels of delicate lattice; or inside the house, the grates and stair balustrades were just as good.

The railings begin with the very fine design of the inclosure to St. Paul's—great baluster-shaped forms of beautiful profile; the railings at St. Martin's-in-the-Fields following the same model; and there is a late example in Bloomsbury Square, where large rounded posts of this kind are used occasionally between straight uprights. Others have wide pilaster posts at intervals, like a beautiful railing close to Apsley House in Piccadilly; or others have solid disks placed in the lozenges of lattice work, as on the west side of Lincoln's Inn. Even the ordinary area railing of straight bars has cast knobs and vase-like forms on the top, entirely good in their way, and everything so compact that you never see parts fractured.

The balcony railings are very light—a network of lattice. For perfect fitness, a natural and unashamed treatment of casting in iron, they could not be bettered.

We never think of comparing them with wrought iron to their disadvantage; both are excellent in different categories, and we might as well compare London Bridge to Lady day; whereas, modern castings do invite comparison with wrought iron, by an infinitely careful ingenuity of pattern making, emulating just those qualities in which to succeed is only the most of all to fail. For not the line, as in wrought work, the bent rod in scrolls, but the plate, plain or pierced, is the primary fact, a panel of equally distributed substance, or it will fracture in cooling. To get the most out of these natural aptitudes—that is art; by the simplest means—that is perfect art. In a word, the ratio of visible effort and economy of apparatus to the ends achieved is the measure of our enjoyment of a work.

The verandas, many of them, are equally excellent, also some of the older lamp posts. For the stair railings, the usual plan is to have a wide, flat baluster of open work, one to each step, the metal very thin toward the view, and perhaps beaded. I remember to have seen a wide stone stair of the town hall at Cherbourg; there was a continuous balustrade of cast plates of iron, pierced with apertures into forms, each edged all round with a delicate raised fillet; it was certainly successful. The French use cast iron largely, and much of it designed with better taste than our own, and much, I believe, with worse. Where it is the work of one of their abler architects, as in the St. Genevieve Library, or the Northern Station, or the Palais de Justice, it is carefully studied and refined. Doors are also made of it, especially for tombs, and these are suitable, which cannot be said of the elaborate pair of Berlin castings at South Kensington, which may be taken to exemplify the "thou shalt not" of cast iron. A sheet of old designs I have also shows arcaded trellises for gardens, of equally reserved taste.

In Italy, also, cast iron has been used for balconies, grilles, and that sort of thing; the turned baluster is a favorite form.

The grates that fill the older houses in London are, for the most part, of excellent design, and remarkable examples of careful casting; some are quite plain, with just a moulding or two, and others are fluted and beaded all over with tiny ornament on flat surfaces; the simplicity of the general forms saves the ornament from being worrying. A very beautiful grate of this sort was designed some years since by Mr. Philip Webb. There are also a great number and variety of knockers.

It is interesting to find in the East a school of casting in metals, poles asunder to our own, especially in its appreciation of the iron; there without doubt the abstract and absolute quality of the metal is admired, apart from the mere accident of its comparative cheapness. Japan is particularly famous for its iron workings, but casting is also well known in China. Some years ago a chain of cast iron, of antique Chinese make, was shown at a meeting of the Archæological Association. Bells and many other objects were also known. But the most wonderful works of iron are the sculptured *tsubi* or sword hilts of Japan now treasured in the cabinets of collectors all over Europe, as well as in Japan itself, each one of tens of thousands a marvel of design and skillful handicraft.

Iron has been also largely used as a basis for incrusting other colored metals upon in raised designs, but those works that especially belong to us this evening are the cast iron tea kettles and vases, of which great numbers have been brought to England, every one a truly individual work of art, fresh in design, and a wonderful example alike of casting, of decorative sense, surface texture, and color. Mr. Phene Spiers has been kind enough to lend me two or three examples. A vase is not so large as some, but an interesting

article of workmanship. The kettles are most charming, one with a slightly sketched band or fret ornament, and a surface that artfully reproduces the accidental handling of the wax original. The color, a fine reddish gray, is entirely beyond my knowledge to suggest how it is obtained. The smaller and, I suppose, much earlier example is even more fascinating; about the size and shape of a small glue pot, with slightly sunk disks, containing inscriptions in soft floating relief, and the surface clean untouched iron, with all the rough texture of the granular particles.

There are a few examples at South Kensington, a small beast and two kettles. These are damascened in silver, and the lids are of precious enamel, which sufficiently shows that the artist delighted in his iron as a material of special and singular beauty.

Dr. Dresser's book tells us these kettles were modeled in wax on a core, and the model was destroyed in the first casting, so that repetition was impossible without remodeling, and who would remodel without variation? The model finished, a thin batter of very fine clay-like sand was mixed with water and spread over the model; a second and other coats of a coarser material followed, and then hard sand was pressed solidly around the whole. When dry, it was put in a muffle and the wax evaporated, the metal afterward occupying its place, as in the well known *cire perdue* method, by which the best works of bronze are cast.

The first mentioned example of Mr. Spiers' and a kettle here of my own, which is signed by the same Japanese craftsman, are, however, certainly cast in piece mould, the first in three sections and the second in two pieces. It is of singular beauty in the melon form of the body, with the wrinkled and pitted surface of the fruit given in the modeling, the resulting

FIG. 5.—JAPANESE KETTLE.

texture partly shining where rubbed and dull in the hollows. The seam of the mould shows without any disguise right round the body, certainly an added beauty and interest.

When cared for thus, and not degraded by mere commercial production, which values the iron only—as Sir John Maundeville said, the people of India worshiped the ox "for his meekness and for the profit that comes of him"—when cared for, the metal has a distinct place; it is our treatment only that is ignoble.

Again, let me say, the position I want to make clear as the point of view of these notes is not at all a claim to widen the application of iron, or that it is in any degree superior to other materials. Each material is the best, and our use of iron castings is sufficient, indeed excessive in all probability; but the claim is that if we elect so to use iron, we can do so for the direct "spiritual," if I may so use the word, appeal of the metal to the imagination; or, secondly, if for humbler and utilitarian reasons it must be good in work and in thought—a work of art. Even the purposes which the worst and most offensive examples have served might, for the greater part, actually have been filled by cast iron if the work had been naturally done; thought of first as use, then as beauty, and never as an imitation, but honest, simple, and delighting in itself—the property, that is, of being cast. Let us think of even the most irritating of these, the cast iron foliage on doors, always fragile, feeble, and false; but if we begin by appreciating the modeling as the essential factor, we may stud the door over with bosses or disks, put cross ledges of thick iron with modeled devices, cover the doors with plate, or fret it with ribs bolted on.

If the uses are not few, the methods of treatment are many. We must, however, accept the necessary limitations that sculpture or ornament must be modeled, not carved, wherever it is proposed that the finished result should be a casting either in metal or other materials. The base may be wood and the ornament modeled in applied wax, which Viollet-le-Duc has stated to be the old method. The ornament, whatever it is, must be a surface decoration of a general simple structural form.

Repetition is of the very nature of cast work, and hence the same form as we have seen was often many times impressed in the same mould. Repetition of a few simple elements in different combinations made great actual variety possible, as in the firebacks.

As to surface, rust is without any doubt the natural treatment, and I believe we might well let nature have it so on occasion. Let us suppose a relief good in design, slight in finish, of the best iron, and absolutely untouched from the mould; put up under some simple pent, it will gradually acquire color and texture—too much of both, you think, but I am not sure. Remember, first of all, how frightened we are of beauty; and that natural color and naturally acquired texture are the very adornments to beauty herself. A joke in Japan tells how the new servant maid from the country polished off Time's lovely tarnish from a silver vessel, "to make it look bright and new." The joke would appear pointless to us, even applied to the tombs of Westminster. Decay is really much less than we suppose, especially on large rounded surfaces, and with even a small but constant amount of friction the metal keeps free of rust, or probably acquires a weather skin. Posts that block up roadways (of which there are a good many in Bloomsbury), or the parapet of Westminster Bridge, are examples; internal work, like the finely designed gratings in Kensington Museum, becomes quite polished.

Galvanizing, the modern version of the tinning which, applied to iron, is as old as Theophilus, is a valuable process. Galvanizing and good oil gilding, right over the surface, would probably be a perfect protection, or the galvanizing might be lacquered and varnished in one of many lustrous tints, or in black and gold patterns, like the iron beams of large scales, one of the few simple decorations still done traditionally.

The black of Barff's process is also a valuable method; the Japanese set much store on a black oxide.

Electro bronzing is another available method of which the French make use, and the dogs at Kensington are examples. Pliny tells us a statue at Rhodes was made of a iron and copper for the sake of the color. We find it possible to get Japanese workmen here to furnish out a shilling show. Would it not be possible to get one or two to instruct us in their processes in iron working, and especially in finishing and coloring the surfaces?

For some work oiling or varnishing may be sufficient, or thin Berlin black; in many cases, of course, painting is really necessary, for which I would recommend white, gray, or black as constant colors, although the real red of the post boxes is not an example to be followed. Simple blackleading, too, is to be entirely approved.

Some old grates are inlaid in brass, which forms flush patterns on the surface. Lead might also be suggested, say for patterns and inscriptions on flat slabs, and might be merely beaten into the hollows left in the casting; or even cements and mastics might be so inlaid, if only properly designed. Turning might be used to finish the forms of balusters of severe classic patterns.

In conclusion, this business of iron founding is such a vast and important industry for England, that any one might be proud to be engaged in it. A sense of beauty and a reputation for skill are also (but it is a degradation to put it in this form) very marketable commodities. How would it be, do you think, even in this severely "practical" present, while not neglecting necessary commercial conditions, to foster within that a school of art in iron founding, in which sons of the house, gentlemen in education, should yet be proud to work as artisans? I entirely believe that manufacture in almost any of its branches (to take Napoleon's phrase) would be "a career open to talents," especially now as we have heard "the professions are played out." With due training and capability, a reputation and some degree of success is almost certain to be obtained in a craft considered and practiced as an art. But even those who make art serve them in some degree, do it by trying to satisfy this or that in taste in this or that style; they do not, as they should, establish a school of production, with Cellini the founder, Maestro Giorgio the potter, or our own Chippendale the cabinet maker.

If our prosperity depends on international commerce, beauty is at once the most attractive and the cheapest of all inducements, and with honesty in the wares the only lasting one. Would it not conserve energy and subserve dignity if advertising were not the only art practiced in so many manufactories? If the wares are good, the buyer should be the seeker. All these things are so curiously and closely interwoven, that bad art goes with bad commerce, bad goods, bad society. Belgian cinder girders and riots of Charleroi. It is true in every department of work, of all materials, and of every form of pay, what the ironmaster said to Emerson: "There's always good iron to be had; if there's cinder in the iron, 'tis because there was cinder in the pay."

NEW YORK CITY AQUEDUCT: ITS ENGINEERING FEATURES AND DESIGN.*

ALEX. CRAWFORD CHENOWETH, Engineer in Charge, Croton Aqueduct.

THE opinion of engineers and others who have given the subject of additional water supply to the city of New York their attention and study, and their selection of the Croton River and water shed, have been well founded upon numerous investigations. The consideration of other sources, with a supposition that the Croton could not be relied upon to furnish enough water for immediate demands, was under serious discussion, until the capacity of the Croton water shed to furnish a minimum supply of 250,000,000 gallons per day was determined from its meteorological history. The whole question was narrowed down to the selection of plans and means to secure sufficient storage, and to conduct the water to the city. The plans for the utilization of the waters of the Croton basin were, therefore, to combine a simplicity of construction, embracing economy in their design, large storage capacity, and a conduit from the Croton River to New York City.

The erection of numerous small reservoirs for storage purposes had been under consideration by the Board of Public Works prior to and during the years 1857 and 1858. Departing from the original plan, it was proposed in place of numerous small dams to build a large one on the Croton River at Quaker Bridge, about four and one-half miles above the mouth of the river, forming a reservoir of 3,635 acres in area, with a storage capacity of about 32,000,000,000 gallons, above the level of the proposed new aqueduct. This dam will receive the entire drainage of the 361 square miles of water shed, including about 23 square miles below the present Croton Lake, not included in any previous plans or calculations. The most economical means for conducting the waters garnered by a system of reservoirs, or a single dam, was by means of a conduit to New York City, constructed of masonry, circular in form, with a capacity to deliver 250,000,000 gallons of water per day, the conduit to be in tunnel wherever possible.

This plan has the advantage of being almost wholly in rock tunnel, securing the greatest possible strength and stability of structure, with the least cost for supervision and maintenance after completion. The prominent features of the entire plan therefore are a large reservoir to receive the entire drainage of the Croton water shed, and capable of holding 32,000,000,000 gallons of water above the level of the aqueduct.

The Croton water shed is located some thirty miles north of New York City, in the jurisdiction of the State of New York, having a catchment equal to an area of 361·8 square miles, with an average yearly rainfall equal to 45·97 inches, an average yearly flow of 135,400,000,000 gallons, or a daily flow of 371,600,000 gallons. This was determined from a meteorological history covering 17 years.

It had long been felt that the capacity and supply of the old system, erected when the population of the city was 350,000, were inadequate for the needs of a population of over 1,500,000, and that steps must be taken to increase the present supply. The Aqueduct Commission was accordingly created by the Legislature of New York in the year 1883, with power to provide an additional water supply.

Plans and specifications were presented by the Board of Public Works, specifying dams and reservoirs to be located at Quaker Bridge, in the Croton River basin, with a dam at Muscoot Mountain, in the upper Croton basin, together with a dam at Sodom, known as the West Branch Reservoir. After many public hearings and discussions the commission decided that the new aqueduct should be constructed with a conduit having an inside clear area equal to that of a circle of the internal diameter of fourteen feet, locating its northern terminus at Croton Lake, and afterward its southern terminus at Manhattan Valley.

The 9th of April, 1884, the plans relating to a conduit or tunnel thirty and three-fourths miles in length were adopted from gate house at One Hundred and Thirty-fifth Street to Croton Lake. The water was to be conducted to the reservoir in Central Park from the One Hundred and Thirty-fifth Street Gate House, by means of pipes, a distance of two and three-eighths miles, making the total length of aqueduct thirty-three and one-eighth miles. The entire aqueduct is practically finished and ready for the introduction of water, its use being debarred only by some minor details. The water will enter the tunnel through a gate house located near the present Croton dam, this being constructed so as to receive water at an elevation of 140 feet above tide at the invert. Two other entrances are provided, one at elevation 166 and one at 184, discharging in Central Park Reservoir. The elevation of the flow line of Quaker Bridge Reservoir will be 200 feet above tide. The maximum elevation of the receiving reservoir in Central Park is 113 feet, the bottom 79 feet. The elevation of point of discharge is 104 feet; the hydraulic grade line at Central Park 113 feet, the total fall from water level of greatest flow in the aqueduct at Croton dam to high water in Central Park Reservoir being 33·8 feet, the distance being thirty-three and one-eighth miles.

The cross-section of the tunnel is in the shape of a horseshoe, this modification from a circular cross-section having been made with a view to economy in blasting out the rock, the natural inclination of which was to assume a square shape rather than a circular one; the hydraulic area of cross-section remains the same as that adopted by the commission, and extends without change twenty-five miles south of Croton Lake, with a hydraulic slope of 0·7 of a foot per mile, giving a velocity of four feet per second, and not being under flow pressure.

The remaining five miles being under flow pressure, by reason of a change in elevation, the diameter was reduced to twelve feet three inches. The hydraulic grade being raised increased the static head, and the capacity to deliver the amount of water required permitted a decreased diameter. The tunnel approached the surface four times in the total distance, enabling the work to be prosecuted by means of open cuts. Headings were driven in the rock north and south of thirty-eight shafts together with the portals in open cuts.

	Feet.
The greatest depth of shaft from surface.	350
The least depth of shaft from surface....	28
Aggregate depth of shafts excavated.....	4,491
Average depth of tunnel underground...	170

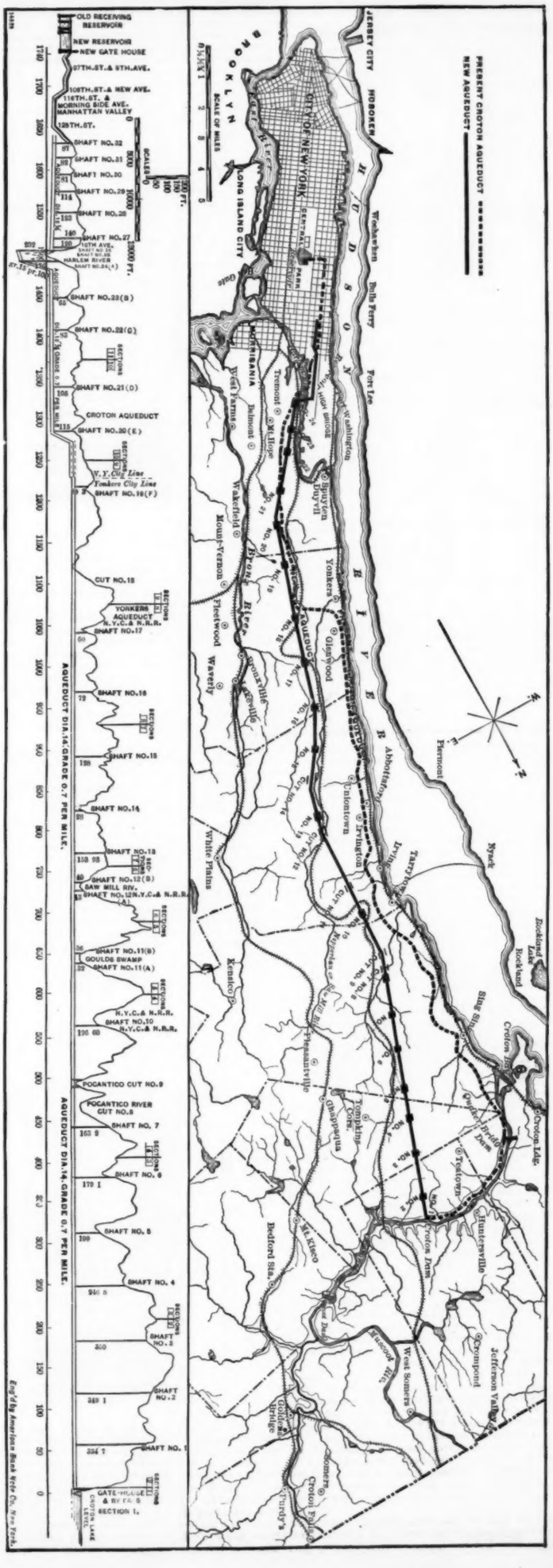
The work of excavating the tunnel proper was begun March 7, 1885, and finished July 7, 1888, the time being three years and four months. The remarkably short time occupied in excavating the tunnel was due to the advance in mechanical appliances for drilling and excavating rock. An opportunity was afforded to demonstrate the efficiency of plants furnished by the most prominent manufacturers. The Ingersoll drills gave by far the best satisfaction under all variations and conditions.

A record of monthly progress was kept, and from this the data of four months' working were selected from February 1 to June 3, 1886, choosing headings that were free from accidents, strikes, and unusual delays. The results are given herewith:

	Shaft No.		Feet.
Best five headings, using Ingersoll drills exclusively.....	23	—south,	219·8
	23	—north,	209·1
	22	—north,	197·5
	11a	—north,	185·8
	4	—north,	182·4
			994·6
Average.....			198·9

	Shaft No.		Feet.
Best five headings, using Rand drills exclusively.....	20	—south,	152·5
	15	—south,	147·8
	14a	—south,	134·0
	15	—north,	129·0
	19	—north,	119·0
			682·3
Average.....			136·5

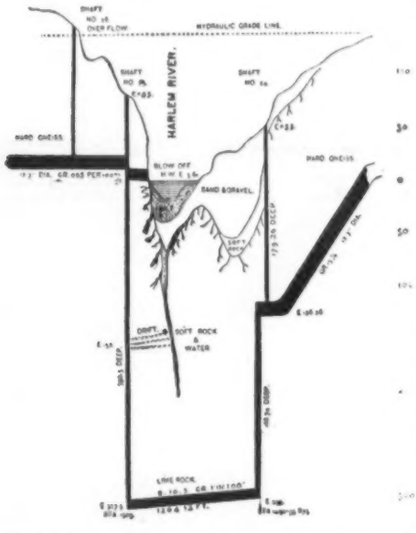
* A paper read before the Franklin Institute, Philadelphia, Pa., Oct., 1889. From the *Journal* of the Institute.


OLD RECEIVING RESERVOIR
NEW RESERVOIR
NEW GATE HOUSE
97TH.ST.& 5TH.AVE.
106TH.ST.& NEW AVE.
116TH.ST. & MORNING SIDE AVE. MANHATTAN VALLEY
125TH.ST.
SHAFT NO.22
SHAFT NO.21
SHAFT NO.20
SHAFT NO.29
SHAFT NO.28
SHAFT NO.27
10TH AVE.
HARLEM RIVER
SHAFT NO.23(B)
SHAFT NO.22(C)
SHAFT NO.21(D)
CROTON AQUEDUCT
SHAFT NO.20(E)
Y.C.& N.R.R.
Yonkers City Line
SHAFT NO.19(F)
CUT NO.18
YONKERS AQUEDUCT N.Y.C.& N.R.R.
SHAFT NO.17
SHAFT NO.16
SHAFT NO.15
SHAFT NO.14
SHAFT NO.13
SHAFT NO.12(B)
SAW MILL RIV.
SHAFT NO.12 N.Y.C.& N.R.R.
SHAFT NO.11(B)
GOULDS SWAMP
SHAFT NO.11(A)
N.Y.C.& N.R.R.
SHAFT NO.10
N.Y.C.& N.R.R.
POCANTICO CUT NO.9
POCANTICO RIVER CUT NO.8
SHAFT NO. 7
SHAFT NO. 6
SHAFT NO. 5
SHAFT NO. 4
SHAFT NO. 3
SHAFT NO. 2
SHAFT NO. 1
GATE-HOUSE & BY-PS. 5
SECTION 1.
AQUEDUCT DIA.14. GRADE 0.7 PER MILE.
AQUEDUCT DIA.14. GRADE 0.7 PER MILE.
BROOKLYN
JERSEY CITY
HOBOKEN
HUDSON
RIVER
EAST RIVER
LONG ISLAND CITY
CITY OF NEW YORK
CENTRAL PARK
Weehawken
Bull Ferry
Fort Lee
Guttenberg
West Hoboken
Union Hill
Hoboken
Bergen
Harrison
Newark
Kearny
Belleville
Nutley
Passaic
Clifton
Paterson
Hackensack
Secaucus
Jersey City
Hudson City
Bayonne
Staten Island
Port Richmond
Elizabeth
Rahway
Perth Amboy
Woodbridge
Metuchen
Rutherford
Carlstadt
Lyndhurst
Arlington
Kearny
Harrison
Newark
Orange
Bloomfield
Montclair
Glen Ridge
Caldwell
Verona
Cedar Grove
Little Falls
Pompton
Wayne
Totowa
Paterson
Hawthorne
Ridgewood
Glen Rock
Ramsey
Mahwah
Suffern
Tuxedo
Greenwood Lake
Warwick
Florida
Monroe
Chester
Goshen
Middletown
Port Jervis
Deposit
Hancock
Delhi
Stamford
Walton
Delaware
Sullivan
Orange
Rockland
Putnam
Dutchess
Ulster
Greene
Columbia
Rensselaer
Albany
Schoharie
Montgomery
Fulton
Saratoga
Washington
Warren
Essex
Hamilton
Herkimer
Oneida
Madison
Onondaga
Cayuga
Seneca
Tompkins
Cortland
Broome
Tioga
Chemung
Schuyler
Steuben
Allegany
Cattaraugus
Chautauqua
Erie
Niagara
Orleans
Genesee
Wyoming
Livingston
Ontario
Yates
Monroe
Wayne
Oswego
Lewis
St. Lawrence
Franklin
Clinton
Essex
Hamilton
Fulton
Saratoga
Washington
Warren
Rensselaer
Albany
Schoharie
Montgomery
Otsego
Delaware
Chenango

One Hundred and Thirty-fifth Street, with a rising slope of 0·065 per 100 feet, in order to drain that portion of the tunnel south of the Harlem into the Harlem River by an adit emptying into the river at shaft 25, situated on the south bank of the Harlem. Shafts 24 and 25 were constructed for the purpose of draining the tunnel under flow pressure north and south of the Harlem River, shaft 25 also serving as a pumping station to free the siphon under the river. The tunnel ends at the gate house located at One Hundred and Thirty-fifth Street, and the water is then conducted to the reservoir in Central Park by twelve lines of iron pipe, three feet in diameter. Four waste weir gate houses are located on the line, one at Pocantico River, near Tarrytown, nine and one-half miles south of Croton Lake; the second, at Saw Mill River, six and one-fourth miles further south, near Ardsley; the third at Tibbets Brook, five and one-half miles further; and the fourth at the Harlem River, seven miles below. Three gate houses serve to control and regulate the water supply through the aqueduct; the largest at Croton dam, the entrance; the second at the south end of the tunnel, One Hundred and Thirty-fifth Street, where the pipe line begins; and the third at the final terminus, in Central Park. The character of the rock varied considerably; hard, granitic, and syenitic gneiss rock was encountered, also lime rock, a soft laminated, micaceous gneiss and mica schist appeared in stretches. Disintegrated talcose rock occurred at shaft 18 south, and crushed in the strongest timbering. At shaft 30 south, some 300 feet of the tunnel were lined with iron in the form of rings bolted together, surrounded with brick and backed with rubble masonry. This was found necessary in such bad ground. Nearly every variety of tunnel experience was met with in this work.

The entire tunnel is lined with brick from end to end, forming a wall sixteen to twenty-four inches thick, and filled in from brick lining to rock face with rubble masonry. In order to obtain room for this lining the tunnel had to be excavated to a clear diameter equal to eighteen feet along the section, with an internal diameter of fourteen feet, and to fifteen feet in that part twelve feet three inches in diameter.

By far the greatest feature of the system designed for an additional water supply is the erection of Quaker Bridge dam and reservoir. Its utility and necessity are conceded, though its construction has not been finished. Its successful and permanent construction will undoubtedly become an established fact, in view of the real design and intention for which the new aqueduct has been constructed. The total height at center will be 265 feet;



the width or thickness at base will be 216 feet; width at top, 20 feet; its length at top, 1,500 feet; elevation of base, — 52 feet; elevation of flow line, + 200 feet; elevation of flood line, + 206 feet; elevation of top of rail, + 213 feet. This dam has been designed as a straight dam, and has meet with difference of opinion in regard to this feature from numerous engineers.

In connection with Quaker Bridge reservoir, the erection of a dam and reservoir at Muscoot Mountain, six miles above Croton Dam, is contemplated as a necessary auxiliary to Quaker Bridge reservoir. The dam would cover this territory with its back water, and would serve a sanitary purpose. In case the reservoir were drawn down at any time, the surrounding country would not be laid bare to the sun's rays, the consequences of which would be the serious contamination of the water. In order to acquire an increased storage of water above the present supply, pending the final determination and erection of the Quaker Bridge reservoir, a selection of a site on the west branch of the Croton River, near Sodom, was resolved upon. The reservoir is nearing its completion. One of the features of the Sodom dams and reservoirs is a double dam, two distinct drainage areas having two dams connected by a tunnel, so that the water can pass freely from one to the other.

The capacity of the Sodom or east branch reservoirs is about 10,000,000,000 gallons. The erection of this dam about doubles the existing storage in reservoirs and lakes located in the Croton water shed.

The Sodom or west branch reservoirs are impounded by small dams, one of them being of masonry 500 feet long, and the other an earth dam with masonry core. The Department of Public Works is erecting a reservoir on the Amawalk River, a small tributary, near the site selected for the Muscoot dam, with a capacity of 7,000,000,000 gallons. This, together with existing reservoirs and lakes, and the west branch reservoirs now building, will give a total storage of 26,000,000,000.

It can be readily seen that all the water in the Croton water shed will, in a few years, be stored up for use. This has led to the investigation of the means and measured daily consumption of water in New York.

Estimate by Mean Curve of Consumption, Daily.		Measured Consumption.*	
Year.	Million Gallons.	Year.	Million Gallons.
1842	12·0	1842	12·0
1860	49·0		
1861	51·5		
1862	54·0		
1863	56·5	1863	54·4
1864	59·2		
1865	62·0		
1866	64·8	1866	66·0
1867	67·5	1867	72·0
1868	70·5	1868	78·0
1869	73·5	1869	75·0
1870	77·0	1870	70·0
1871	80·0	1871	79 0
1872	83·5	1872	81·0
1873	87·3	1873	88·0
1874	91·0	1874	92·0
1875	95·0	1875	95·0

* Commissioner's Report, August 12, 1879.

ESTIMATE OF FUTURE CONSUMPTION OF WATER IN NEW YORK CITY BY PROLONGING THE MEAN CURVE OF PAST CONSUMPTION.

Year.	Million Gallons.	Increase Million Gallons.	Year.	Million Gallons.	Increase Million Gallons.
1876	98 0	...	1889	168·0	7·0
1877	102·0	4·0	1890	176·0	8·0
1878	106 0	4·0	1891	184·0	8·0
1879	110·5	4·5	1892	193·0	9·0
1880	115·0	4·5	1893	202·0	9·0
1881	120·0	5·0	1894	212·0	10·0
1882	125·0	5·0	1895	222·0	10·0
1883	130 5	5·5	1896	234·0	12·0
1884	136 0	5 5	1897	246·0	12·0
1885	142·0	6·0	1898	258·0	12·0
1886	148·0	6·0	1899	272·5	14·5
1887	154·0	6·0	1900	290 0	17·5
1888	161·0	7·0			

The evidence of this record is that the Croton must be supplemented from some other source within a few years. The total capacity of the two aqueducts—the old and the new one—together being 350,000,000 gallons of water per day, their supply will answer all purposes for some time to come.

New York City, November 18, 1889.

SIBLEY COLLEGE LECTURES.—1889-90.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

II.—CIRCULATION OF WATER IN STEAM BOILERS.

By GEO. H. BABCOCK, of New York City.

YOU have all noticed a kettle of water boiling over the fire, the fluid rising somewhat tumultuously around the edges of the vessel and tumbling toward the center, where it descends. Similar currents are in action while the water is simply being heated, but they are not perceptible unless there are floating particles in the liquid. These currents are caused by the joint action of the added temperature and two or more qualities which the water possesses.

1. Water, in common with most other substances, expands when heated; a statement, however, strictly true only when referred to a temperature above 39° Fah. or 4° C., but as in the making of steam we rarely have to do with temperatures so low as that, we may for our present purposes ignore the exception.

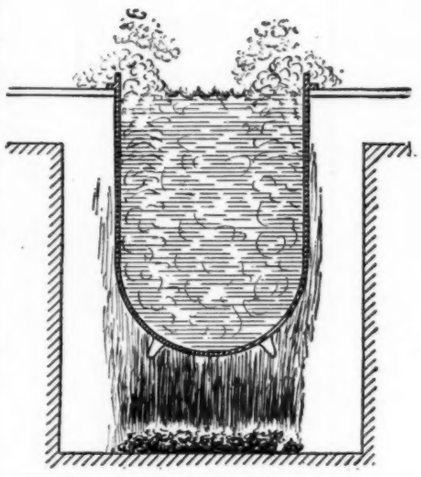
2. Water is practically a non-conductor of heat, though not entirely so. If ice-cold water was kept boiling at the surface, the heat would not penetrate sufficiently to begin melting ice at a depth of three inches in less than about two hours. As therefore the heated water cannot impart its heat to its neighboring particles, it remains expanded and rises by its levity, while colder portions come to be heated in turn, thus setting up currents in the fluid.

Now, when all the water has been heated to the boiling point corresponding to the pressure to which it is subjected, each added unit of heat converts a portion, about seven grains in weight, into vapor, greatly increasing its volume, and the mingled steam and water rises more rapidly still, producing ebullition such as we have noticed in the kettle. So long as the quantity of heat added to the contents of the kettle continues practically constant, the conditions remain similar to those we noticed at first, a tumultuous lifting of the water around the edges, flowing toward the center and thence downward; if, however, the fire be quickened, the upward currents interfere with the downward, and the kettle boils over. (Fig. 1.)

It is not recorded by whom and when this action of water when heated was first noticed, though it is fair to refer it to remote antiquity. But notwithstanding it has long been well known, not until a comparatively recent date does any one seem to have considered that these currents were a necessary part of the action of water within a steam boiler, possibly because, being closed, one could not easily see what the action was therein. And even now there are more boilers made with no provision for these currents than with. The first notice we find of the recognition of its necessity is in a description of Griffiths' water tube boiler of 1821, in Mr. Alexander Gordon's "Treatise on Elemental Locomotion," about 1832, in which he says that "the principal difficulty Mr. Griffiths had to contend with was the liability to which the boiler was exposed of having all the water blown out of the tubes by force of the steam generated in the lower part, and to the want of a due circulation or ability of the water to return."

Shortly after, in 1825, we find this difficulty provided for by large return pipes, in the patent of Joseph Eve, and in 1826 in the U-tube boiler which Gurney put upon his road locomotives. In 1831 Jacob Perkins patented means of separating the currents in small tubes, and also in large boilers, and providing for a rapid circulation of the water therein. Since that time various inventors and engineers have recognized its importance and provided more or less intelligently for it, but even at the present day great ignorance prevails as

Fig. 1.

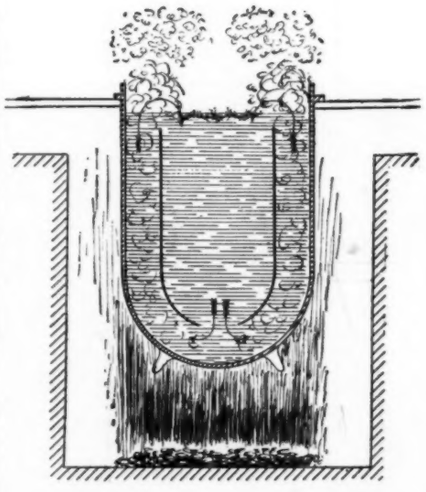


to the importance of circulation and the proper means for securing it in practice.

Let us go back to our kettle of water. We found that when we forced the fire too fiercely, it boiled over. If now we put in the kettle a vessel somewhat smaller (Fig. 2), with a hole in the bottom, and supported at a proper distance from the side, so as to separate the upward from the downward currents, we can force the fires to a very much greater extent without causing the kettle to boil over, and when we place a deflecting plate so as to guide the rising column toward the center, it will be almost impossible to produce that effect. This is the invention referred to as patented by Perkins in 1831, and forms the basis of very many of the arrangements for producing free circulation of the water in boilers which have been made since that time. It consists in dividing the currents so that they will not interfere each with the other.

But what is the object of facilitating the circulation of water in boilers? Why may we not safely leave this to the unassisted action of nature, as we do in culinary operations? We may if we do not care for the three most important aims in steam boiler construction, namely, efficiency, durability, and safety, each of which is more or less dependent upon a proper circulation of the water. As for efficiency, we have seen one proof in our kettle. When we provided means to preserve the circulation, we found that we could carry a hotter fire and boil away the water much more rapidly than before. It is the same in a steam boiler. The rapid current of water carries away the bubbles of steam as fast as they are formed upon the surface and supplies their place by other particles of water, which in their turn carry off the heat by vaporization or otherwise. Thus the efficiency of the surface is greatly increased. And

Fig. 2.



we also noticed that when there was nothing but the unassisted circulation, the rising steam carried away so much water in the form of foam that the kettle boiled over, but when the currents were separated, and an unimpeded circuit was established, this ceased, and a much larger amount of steam was delivered in a comparatively dry state. Thus circulation increases the efficiency in two ways: It adds to the ability to take up the heat, and decreases the liability to waste that heat by what is technically known as priming. There is yet another way in which, incidentally, circu-

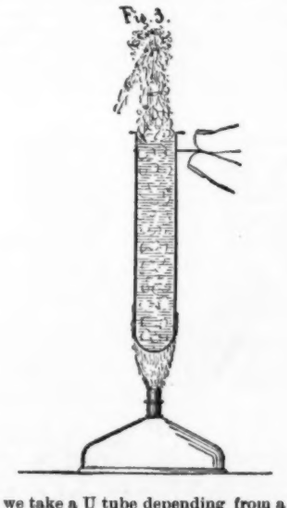
lation increases efficiency of surface, and that is by preventing in a greater or less degree the formation of deposits thereon. Most waters contain some impurity, which, when the water is evaporated, remains to incrust the surface of the vessel. This incrustation becomes very serious sometimes, so much so as to almost entirely prevent the transmission of heat from the metal to the water. It is said that an incrustation of only ⅛ inch will cause a loss of 35 per cent. in efficiency, and that is probably within the truth in many cases. The average conductivity of underground strata, with which boiler incrustations may fairly be compared, as given by Forbes and Sir William Thomson, is but one-thirtieth of that of iron, so that an eighth of an inch incrustation added to the surface of the boiler will have the same effect as adding a second plate of iron four inches thick. Circulation of water will not prevent incrustation altogether, but it lessens the amount in all waters, and almost entirely so in some, thus adding greatly to the efficiency of the surface.

A second advantage to be obtained through circulation is *durability* of the boiler. This it secures mainly by keeping all parts at a nearly uniform temperature. Until a comparatively recent date, boilers have been built to fulfill the conditions of Rankine's class 1 of highest efficiency. "The convection taking place in the best manner by introducing the water in the coolest part of the boiler and making it travel gradually to the hottest." This class of boiler originated, I think, with the locomotive "Novelty," built by Braithwait & Ericsson, in 1829, for the famous competitive test on the Liverpool and Manchester Railroad, in October, that year, and is known as the "drop-flue" boiler. In it circulation is avoided as far as possible, keeping the bottom as cool as may be and delivering the hottest gases into the flues near the surface of the water. Though, theoretically, this arrangement has some advantages in the abstraction of heat, it renders the boiler exceedingly subject to leaks and repairs, owing to the unequal expansion of the different parts. I have known cases where for years it was necessary to have a gang of boiler makers at work every Sunday, to keep a pair of these drop-flue boilers in working condition. This style of boiler has now almost wholly disappeared, but still many boiler makers build, and engineers recommend, boilers but a little way removed therefrom, wherein absence of adequate circulation of the water causes some portions to remain cold, while others are hot. The way to secure the greatest freedom from unequal strains in a boiler is to provide for such a circulation of the water as will insure the same temperature in all parts.

3. *Safety* follows in the wake of durability, because a boiler which is not subject to unequal strains of expansion and contraction is not only less liable to ordinary repairs, but also to rupture and disastrous explosion. By far the most prolific cause of explosions is this same strain from unequal expansions.

Having thus briefly looked at the advantages of circulation of water in steam boilers, let us see what are the best means of securing it under the most efficient conditions. We have seen in our kettle that one essential point was that the currents should be kept from interfering with each other. If we could look into an ordinary return tubular boiler when steaming, we should see a curious commotion of currents rushing hither and thither, and shifting continually as one or the other contending force gained a momentary mastery. The principal upward currents would be found at the two ends, one over the fire and the other over the first foot or so of the tubes. Between these the downward currents struggle against the rising currents of steam and water. At a sudden demand for steam, or on the lifting of the safety valve, the pressure being slightly reduced, the water jumps up in jets at every portion of the surface, being lifted by the sudden generation of steam throughout the body of water. You have seen the effect of this sudden generation of steam in the well-known experiment with a Florence flask, to which a cold application is made while boiling water under pressure is within. You have also witnessed the geyser-like action when water is boiled in a test tube held vertically over a lamp. (Fig. 3.)

Fig. 3.



If now we take a U tube depending from a vessel of water (Fig. 4) and apply the lamp to one leg, a circulation is at once set up within it, and no such spasmodic action can be produced. This U tube is the representative of the true method of circulation within a water tube boiler properly constructed. We can, for the purpose of securing more heating surface, extend the heated leg into a long incline (Fig. 5), when we have the well-known inclined tube generator. Now, by adding other tubes, we may further increase the heating surface (Fig. 6), while it will still be the U tube in effect and action. In such a construction the circulation is a function of the difference in density of the two columns. Its velocity is measured by the well-known Torricellian formula, $V=\sqrt{2gh}$, or approximately $V=8\sqrt{h}$, h being measured in terms of the lighter fluid. This velocity will increase until the rising column becomes all steam, but the *quantity* or weight circulated will attain a maximum when the density of the mingled steam and water in the rising column becomes one-half that of the solid water in the descending column, which is nearly coincident with the condition of half steam and half

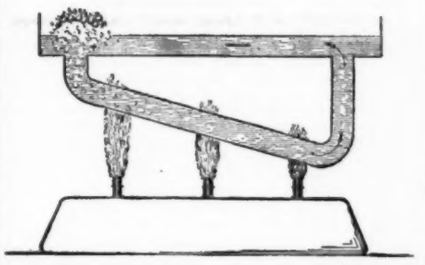
Fig. 4.

water, the weight of the steam being very slight compared to that of the water.

It becomes easy by this rule to determine the circulation in any given boiler built on this principle, provided the construction is such as to permit a free flow of the water. Of course every bend detracts a little, and something is lost in getting up the velocity, but when the boiler is well arranged and proportioned, these retardations are slight.

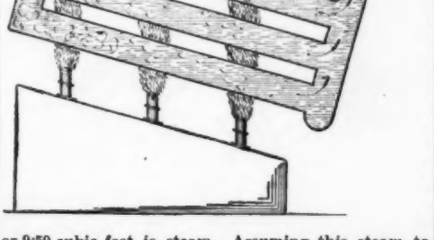
Let us take for example one of the 240 horse power Babcock & Wilcox boilers here in the university. The

Fig. 5.



height of the columns may be taken as four and one-half feet, measuring from the surface of the water to about the center of the bundle of tubes over the fire, and the head would be equal to this height at the maximum of circulation. We should therefore have a velocity of $8\sqrt{4\frac{1}{2}}=17{\cdot}97$, say 18 feet per second. There are in this boiler fourteen sections, each having a 4" tube opening into the drum, the area of which (inside) is 11 square inches, the 14 aggregating 154 square inches, or 1·07 square feet. This multiplied by the velocity, 17·97 feet, gives 19·18 cubic feet mingled steam and water discharged per second, one-half of which,

Fig. 6.

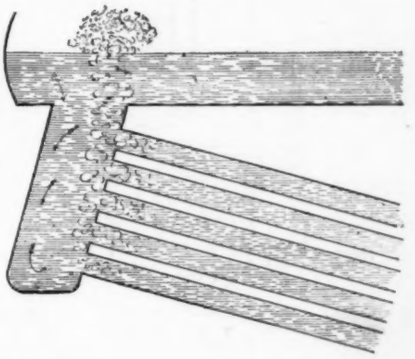


or 9·59 cubic feet, is steam. Assuming this steam to be at 100 pounds gauge pressure, it will weigh 0·258 pound per cubic foot. Hence 2·47 pounds of steam will be discharged per second, and 89·07 pounds per hour. Dividing this by 30, the number of pounds representing a boiler horse power, we get 296·9 horse power, about 23 per cent. in excess of the rated power of the boiler. The water at the temperature of steam at 100 pounds pressure weighs 56 pounds per cubic foot, and the steam 0·258 pound, so that the steam forms but 1·218 part of the mixture by weight, and consequently each particle of water will make 218 circuits before being evaporated when working at this capacity, and circulating the maximum weight of water through the tubes.

It is evident that at the highest possible velocity of exit from the generating tubes, nothing but steam will be delivered, and there will be no circulation of water except to supply the place of that evaporated. Let us see at what rate of steaming this would occur with the boiler under consideration. We shall have a column of steam say four feet high on one side and an equal column of water on the other. Assuming, as before, the steam at 100 pounds and the water at same temperature, we will have a head of 866 feet of *steam* and an issuing velocity of 235·5 feet per second. This multiplied by 1·07 square feet of opening, and 3,600 seconds in an hour, gives 218,600 pounds of steam, which, though only one-eighth the weight of mingled steam and water delivered at the maximum, gives us 7,286 horse power, or *over* 30 *times* the rated power of the boiler. Of course this is far beyond any possibility of attainment, so that it may be set down as certain that this boiler cannot be forced to a point where there will not be an efficient circulation of the water. By the same method of calculation it may be shown that when forced to double its rated power, a point not expected to be reached in practice, about two-thirds the volume of mixture of steam and water delivered into the drum will be steam, and that the water will make 110 circuits while being evaporated. Also that when worked at only about one-quarter its rated capacity, one-fifth of the volume will be steam, and the water will make the rounds 870 times before it becomes steam. You will thus see that in the proportions adopted in this boiler there is provision for perfect circulation under all the possible conditions of practice.

In designing boilers of this style it is necessary to guard against having the uptake at the upper end of the tubes too large, for if sufficiently large to allow downward currents therein, the whole effect of the rising column in increasing the circulation in the tubes is nullified (Fig. 7). This will readily be

Fig. 7.



seen if we consider the uptake very large—when the only head producing circulation in the tubes will be that due to the inclination of each tube taken by itself. This objection is only overcome when the uptake is so small as to be entirely filled with the ascending current of mingled steam and water. It is also necessary that this uptake should be practically direct, and it should not be composed of frequent enlargements and contractions. Take for instance the boiler known in Europe as the De Nayer boiler, copied and sold here under another name. It is made up of inclined tubes secured by pairs into boxes at the ends, which boxes are made to communicate with each other by return bends opposite the ends of the tubes. These boxes and return bends form an irregular uptake, whereby the steam is expected to rise to a reservoir above. You will notice (Fig. 8) that the upward current of steam and water in the return bend meets and directly antagonizes the upward current in the adjoining tube. Only one result can follow. If their velocities are equal the momentum of both will be neutralized and all circulation stopped, or if one be stronger, it will cause a back flow in the other by the amount of difference in force, with practically the same result.

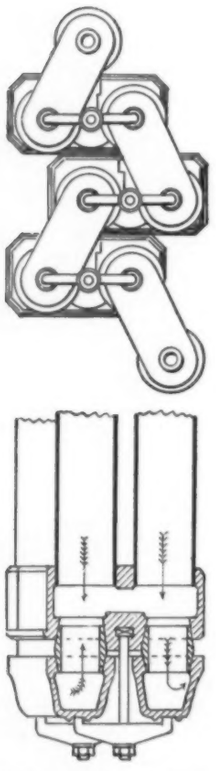
In the original Root boiler, many of which were sold, but of which none are now made, and very few are still in use, the inventor claimed that the return bends and small openings against the tubes were for the purpose of "restricting the circulation," and no doubt they performed well that office; but excepting for the smallness of the openings, they were not as efficient for that purpose as the arrangement shown in Fig. 8.

Another form of boiler, first invented by Clarke or Crawford, and lately revived, has the uptake made of boxes into which a number, generally from two to four tubes, are expanded, the boxes being connected together by nipples (Fig. 9). It is a well-known fact that where a fluid flows through a conduit which enlarges and then contracts, the velocity is lost to a greater or less extent at the enlargements, and has to be gotten up again at the contractions each time, with a corresponding loss of head. Many years ago some one proposed to carry water across the Hackensack River to Jersey City by means of a pipe, which was to be so jointed as to permit of being laid like a cable from a boat and adapt itself to the bed of the river. The joints were to be elbows fitted and bolted so as to permit of motion around the transverse axis; and with an idea to avoid the loss due to the many changes of direction, these elbows were enlarged somewhat like tobacco pipes, with the bowls laid together. To test the matter, a model was made to scale, carefully smoothed on the inside to reduce friction, but when tried it proved that, even with these elbows so carefully shaped to render the enlargement and contractions as gradual as possible, there would have been no head left long before the pipe reached the opposite shore, and the plan was abandoned. The same thing occurs in the construction shown in Fig. 9. The enlargements and contrac-

tions quite destroy the head and practically overcome the tendency of the water to circulate.

A horizontal tube stopped at one end, as shown in Fig. 10, can have no proper circulation within it. If moderately driven, the water may struggle in against

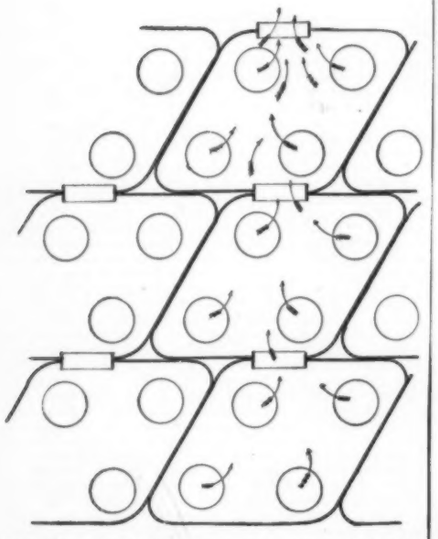
Fig. 8.



the issuing steam sufficiently to keep the surfaces covered, but a slight degree of forcing will cause it to act like the test tube in Fig. 3, and the more there are of them in a given boiler, the more spasmodic will be its working.

I have thus enlarged upon the proper circulation of water in water tube boilers because they seem destined to be the boiler of the future, and because of having seen thirty or forty kinds of water tube and sectional boilers appear and disappear in the last twenty-five years, by far the larger portion of which have failed

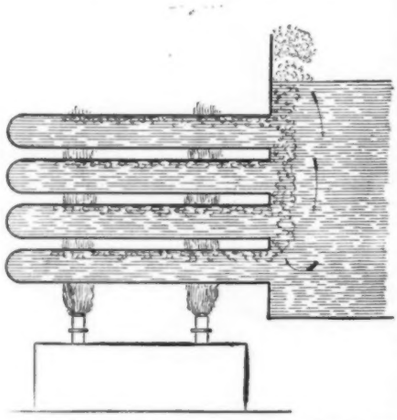
Fig. 9.



through want of adequate provision for such circulation.

The experiment with our kettle (Fig. 9) gives the clew to the best means of promoting circulation in ordinary shell boilers. Steenstrup or "Martin" and "Galloway" water tubes placed in such boilers also assist in directing the circulation therein, but it is almost impossible to produce in shell boilers, by any means, the circulation of all the water in one continuous round, such as marks the well constructed water tube boiler.

The point of entrance of feed water in any boiler has also something to do with the circulation, and much to do with durability. Care should always be taken to introduce it at some point where, if not immediately heated to the temperature of the water in the boiler, it shall not come in contact with any portion of the metal until it is so heated. If introduced into the bottom or the mud drum, it will keep below the hotter water and set up serious strains in the structure. I recollect the late Mr. Dickerson showing with great satisfaction as an evidence of superior economy, on board the Algonquin, that when there was 80 lb. of steam on the boiler he could wash his hands in water drawn from the blow-off cock. Rankine mentions with approbation the same condition in the Earl of Dundonald's boiler, but it is a condition to be avoided always. The feed water should be introduced into the current of hot water, where it will the soonest possible mingle



with and become of the same temperature as the rest of the water.

As I have before remarked, provision for a proper circulation of water has been almost universally ignored in designing steam boilers, sometimes to the great damage of the owner, but oftener to the jeopardy of the lives of those who are employed to run them. The noted case of the Montana and her sister ship, where some $300,000 were thrown away in trying an experiment which a proper consideration of this subject would have avoided, is a case in point; but who shall count the cost of life and treasure not, perhaps, directly traceable to, but, nevertheless, due entirely to such neglect in design and construction of the thousands of boilers in which this necessary element has been ignored? If these few facts and hints may induce you who are to be the engineers of the near future to give due consideration to this important subject when designing the boilers of the future, my aim will have been fulfilled. Thanking you for your kind attention to a subject which, though treating of a flowing liquid, is itself necessarily somewhat dry, I will, in order that a circulation may again be established among you, bid you good night.

A THREE-CYLINDER GAS MOTOR.

Mr. Lalbin, engineer of arts and manufactures, has just constructed a new gas motor which has been recently tested at Nantes upon a boat containing twenty persons. The speed obtained was seven miles per hour.

One of the principal advantages of this motor is its lightness as compared with other gas engines. Thus, a half-horse power motor, which can be applied to a tricycle, weighs but 88 lb.; a one horse power weighs 132 lb.; and the five horse power, which was tested on a boat, as above mentioned, weighs but 440 lb.

This latter, in a vertical plane, occupies a circumference of 100 inches, the eduction pipe included, and the fly wheel, which weighs 110 lb., is but 34 inches in diameter. The gases escape into the water, and the cooling of the cylinders is secured through a small automatic pump.

The petroleum is contained in an iron vessel of 12½ gallons capacity, provided with a screw coupling by means of which it is connected with the carburetor, a sort of box containing wicking. This latter, in the boat referred to, was placed under the deck, and the oil reservoir under one of the seats.

The air sucked in by the motion of the pistons passes through the wicking saturated with petroleum, in the carburetor, and becomes charged with combustible vapors in sufficient quantity, regulated at will by a valve maneuvered by hand. A Leclanche battery produces the spark necessary for igniting the gas.

The consumption of petroleum is eleven ounces per horse and per hour, say a little less than a pint per hour, so with a 12½ gallon reservoir, the five horse power engine is capable of furnishing an effective run of 20 hours.

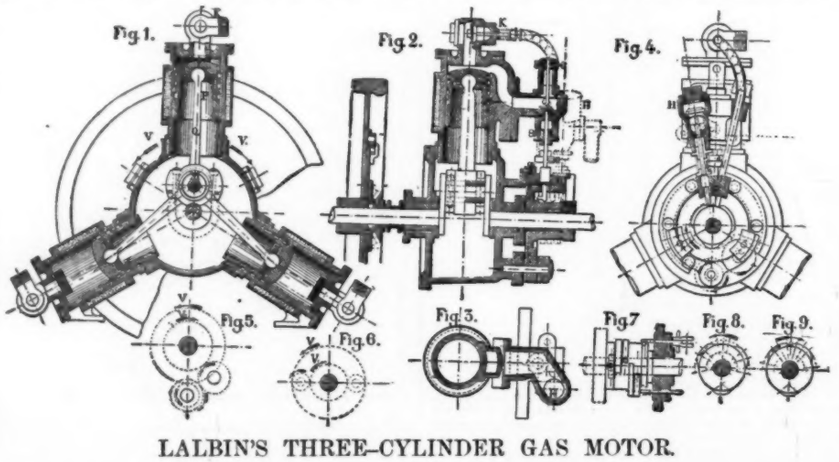
Figs. 1 and 2 give sections of the motor; Fig. 3 gives a transverse section of a cylinder, showing the valve box, H; Fig. 4 gives a front view of a cylinder, with a partial section of the valve box; Figs. 5 and 6 show the arrangement of the gearing for effecting the motion of the cam cylinder, that regulates the distribution; Figs. 7, 8 and 9 represent the arrangement for reversing the motor.

Each cylinder contains a piston, P, connected directly by a connecting rod, Q, with the one crank in common, M, and is provided with a throttle valve, H, and an eduction valve, K.

Ignition is effected at F through an extra current spark, produced by a Leclanche battery. These three cylinders have a common action and control one another, that is to say, the explosion in each cylinder produces, aside from the disposable work, the work necessary for the maneuvering of the cylinder of the piston which is to furnish the subsequent explosion, so as to make it suck the detonating mixture and compress it until the moment at which it is to explode.

The cylinder that carries the cams that control the various services of each cylinder revolves in a direction opposite that of the crank shaft, and at half the velocity, and V in the direction of the crank, and V¹ in that of the distribution. The consequence of such a distribution is that the explosion takes place from one pair of cylinders to another, and with the greatest regularity. As the thrust upon the crank is almost constant, the diameter of the fly wheel may be greatly diminished. The diameter of the pistons of the 5 h. p. engine is five inches, and their stroke is 5¼ inches. The space occupied in a lengthwise direction does not exceed 32 inches, and the motor weighs 440 lb. The engine is reversed through the arrangement shown in Figs. 7, 8 and 9, by means of a lever that causes the cam cylinder to slide in such a way that either the system of cams of Fig. 8 or of Fig. 9 is, according to the direction of running, presented to it under the tappets.

The detonating gas is furnished by the vapors of petroleum mixed with the proper quantity of air, the mixture being varied in such a way as to give the maximum of power, say 400 revolutions, or the minimum, which is 100 revolutions per minute.—*Le Genie Civil.*



LALBIN'S THREE-CYLINDER GAS MOTOR.

SMOKELESS EXPLOSIVES.*

By Sir Frederick Abel, F.R.S.

The production of smoke which attends the ignition or explosion of gunpowder is often a source of considerable inconvenience in connection with its application to naval or military purposes, its employment in mines, and its use by the sportsman, although occasions not unfrequently arise during naval and military operations when the shroud of smoke produced by musketry or artillery fire has proved of important advantage to one or other, or to both, of the belligerents during different periods of an engagement.

Until within the last few years, however, but little, if any, thought appears to have been given to the possibility of dispensing with or greatly diminishing the production of smoke in the application of fire arms, excepting in connection with sport. The inconvenience and disappointment often resulting from the obscuring effects of a neighboring gun discharge, or of the first shot from a double-barrel arm, led the sportsman to look hopefully to guncotton, directly after its first production in 1846, as a probable source of greater comfort and brighter prospects in the pursuit of his pastime and in his strivings for success.

A comparison between the chemical changes attending the burning, explosion, or metamorphosis of guncotton and of gunpowder serves to explain the cause of the production of smoke in the latter case and the reason of smokelessness in the case of guncotton.

While the products of explosion of the latter consist exclusively of gases, and of water which assumes the transparent form of highly heated vapor at the moment of its production, the explosive substances classed as gunpowder, and which consist of mixtures of

* Friday Evening Discourse delivered by Sir Frederick Abel, F.R.S., at the Royal Institution of Great Britain, on January 31, 1890.

saltpeter, or another nitrate of a metal, with charred wood or other carbonized vegetable matter, and with variable quantities of sulphur, furnish products of which very large proportions are not gaseous, even at high temperatures. Upon the ignition of such a mixture, these products are in part deposited in the form of a fused residue, which constitutes the fouling in a firearm, and are in part distributed, in an extremely fine state of division, through the gases and vapors developed by the explosion, thus producing smoke.

In the case of gunpowder of ordinary composition, the solid products amount to over fifty per cent. by weight of the total products of explosion, and the dense white smoke which it produces consists partly of extremely finely divided potassium carbonate, which is a component of the solid products, and, to a great extent, of potassium sulphate, produced chiefly by the burning of one of the important solid products of explosion—potassium sulphide—when it is carried in a fine state of division into the air by the rush of gas.

With other explosives which are also smoke-producing, the formation of the smoke is due to the fact that one or other of the products, although existing as vapor at the instant of its development, is immediately condensed to a cloud composed of minute liquid particles, or of vesicles, as in the case of mercury vapor liberated upon the explosion of mercuric fulminate, or of the aqueous vapor produced upon the ignition of a mixture of ammonium nitrate and charcoal, or ammonium nitrate and picric acid.

Until within the last half dozen years, the varieties of gunpowder which have been applied to war purposes in this and other countries have exhibited comparatively few variations in chemical composition. The proportions of charcoal, saltpeter, and sulphur employed in their production exhibit slight differences in different countries, and these, as well as the character of the charcoal used, its sources and method of production, underwent but little modification for very many years. The same remark applies to the nature of the successive operations pursued in the manufacture of black powder for artillery purposes in this and other countries.

The replacement of smooth-bore guns by rifled artillery, which followed the Crimean war, and the increase in the size and power of guns consequent upon the application of armor to ships and forts, soon called for the pursuit of investigations having for their object the attainment of means for variously modifying the action of fired gunpowder, so as to render it suitable for the different calibers of guns whose full power could not be effectively, or in some instances safely, developed by the use of the kind of gunpowder previously employed indiscriminately in artillery of all known calibers.

In order to control the violence of explosion of gunpowder, by modifying the rapidity of transmission of explosion from particle to particle, or through the mass of each individual particle, of which the charge of a gun is composed, the accomplishment of the desired results was, in the first instance, and indeed throughout practical investigations extending over many years, sought exclusively in modifications of the size and form of the individual masses composing a charge of powder, and of their density and hardness, it being considered that, as the proportions of saltpeter, charcoal, and sulphur generally employed in the production of gunpowder very nearly correspond to those required for the development of the greatest chemical energy by those incorporated materials, it was advisable to seek for the attainment of the desired results by modifications of the physical and mechanical characters of, rather than by any modification in the proportions and chemical characters of, its ingredients.

The varieties of powder which, as the outcome of careful practical and scientific researches in this direction, have been introduced into artillery service from time to time, and some of which, at any rate, have proved fairly efficient, have been of two distinct types. The first of these, produced by breaking up more or less highly pressed cakes of black powder into grains, pebbles, or bowlders, of approximately uniform size and shape, the sharp edges and rough surfaces being afterward removed by attrition (reeling and glazing), are simply a further development of one of the original forms of granulated or corned powder, represented by the old F. G., or small arms, and L. G., or cannon powder. Gunpowder of this class, ranging in size from about 1,000 pieces to the ounce to about six pieces to the pound, has been introduced into artillery service, and certain of them, viz., R. L. G. (rifle large grain), which was the first step in advance upon the old cannon powder (L. G.), pebble powder (P.), and large pebble or bowlder powder (P. 2), are still employed more or less extensively in some guns of the present day.

The other type of powder has no representative among the more ancient varieties; it has its origin in the obviously sound theoretical view that uniformity in the results furnished by a particular powder, when employed under like conditions, demands not merely identity in regard to composition, but also identity in form, size, density, and structure of the individual masses composing the charge used in a gun. The practical realization of this view should obviously be attained, or at any rate approached, by submitting equal quantities of one and the same mixture of ingredients, presented in the form of powder of uniform fineness and dryness, to a uniform pressure for a fixed period in moulds of uniform size, and under surrounding conditions as nearly as possible alike. The fulfillment of these conditions would, moreover, have to be supplemented by an equally uniform course of proceeding in the subsequent drying and other finishing processes to which the powder masses would be submitted.

The only form of powder, introduced into our artillery service for a brief period, in the production of which these conditions were adhered to as closely as possible, was a so-called pellet powder, which consisted of small cylinders having semi-perforations, with the object of increasing the total inflaming surface of the individual masses.

Practical experience with this powder, and with others prepared upon the same system, but with much less rigorous regard to uniformity in such details as state of division and condition of dryness of the powder before its compression into cylindrical or other forms, showed that uniformity in the ballistic properties of black powder could be as well and even more readily secured by the thorough blending or mixing together of batches presenting some variation in regard to density, hardness, or other features, as by aiming at an approach to absolute uniformity in the characters of each individual mass composing a charge.

At the time that our attention was first actively given to this subject of the modification of the ballistic properties of powder, it had already been to some extent dealt with in the United States by Rodman and Doremus, and the latter was the first to propose the application, as charges for guns, of powder masses produced by the compression of coarsly grained powder into moulds of prismatic form. In Russia the first step was taken to utilize the results arrived at by Doremus, and to adopt a prismatic powder for use in guns of large caliber.

Side by side with the development and perfection of the manufacture of prismatic powder in Russia, Germany, and in this country, new experiments on the production of powder masses suitable, by their comparatively gradual action, for employment in the very large charges required for the heavy artillery of the present day, by the powerful compression of mixtures of more or less finely broken up powder cake into masses of greater size than those of the pebble, pellet, and prism powders, were actively pursued in Italy, and also by our own government committee on explosives, and the outcome of very exhaustive practical investigations were the very efficient Fossano powder, or *poudre progressif*, of the Italians, and the bowlder and large cylindrical powders known as P^3 and C^2, produced at Waltham Abbey, which scarcely vied, however, with the Italian powder in the uniformity of their ballistic properties.

Researches carried out by Captain Nobel and the lecturer some years ago with a series of gunpowders differing considerably in composition from each other, indicated that advantages might be secured in the production of powders for heavy guns by so modifying the proportions of the constituents (*e. g.*, by considerably increasing the proportion of charcoal and reducing the proportion of sulphur) as to give rise to the production of a much greater volume of gas, and at the same time to diminish the heat developed by the explosion.

These researches served, among other purposes, to throw considerable light upon the cause of the wearing or erosive action of powder explosions upon the inner surface of the gun, which in time may produce so serious a deterioration of the arm as to diminish the velocity of projection considerably, and so affect the accuracy of shooting, a deterioration which increases in extent in increasing ratio to the size of the guns, in consequence, obviously, of the large increase in the weight of the charges fired.

Several causes undoubtedly combine to bring about the wearing away of the gun's bore, which is especially great where the products of explosion, while under the maximum pressure, can escape between the projectile and the bore of the gun. The great velocity with which the very highly heated gaseous and liquid (fused solid) products of explosion sweep over the heated surface of the metal gives rise to a displacement of the particles composing it, which increases as the surface becomes roughened by the first action upon the least compact portions of the metal, and thus opposes greater resistance; at the same time, the effect of the high temperature to which the surface is raised is to reduce its rigidity and power of resisting the force of the gaseous torrent, and lastly some amount of chemical action upon the metal, by certain of the highly heated non-gaseous products of explosion, contributes toward an increase in the erosive effects. A series of careful experiments made by Captain Noble with powders of different composition, and with other explosives, afford decisive evidence that the material which furnished the largest proportion of gaseous products, and the explosion of which was attended by the development of the smallest amount of heat, exerted least erosive action.

It is probable that important changes in the composition of powders manufactured by us for our heavy guns would have resulted from those researches, but in the meantime two eminent German gunpowder manufacturers had occupied themselves independently, and simultaneously, with the important practical question of producing some more suitable powder for heavy guns than the various new forms of ordinary black powder, the rate of burning of which, especially when confined in a close chamber, was, after all, reduced only in a moderate degree by the increase in the size of the masses, and by such increase in their density as it was practicable to attain. The German experimenters directed their attention not merely to the proportions in which the powder ingredients are employed, but also to a modification in the character of charcoal, and the success attending their labors in these directions led to the practically simultaneous production, by Mr. Heidemann, at the Westphalia Powder Works, and Mr. Duttenhofer, at the Rottweil Works, near Hamburg, of a prismatic powder of cocoa brown color, consisting of saltpeter in somewhat higher proportion, of sulphur in much lower proportion, than in normal black powder, and of very slightly burned charcoal, similar in composition to the charcoal (*charbon roux*) which Violette, a French chemist, first produced in 1847 by the action of superheated steam upon wood or other vegetable matter, and which he proposed for the employment in the manufacture of sporting powder. These brown prismatic powders (or "cocoa powders," as they were termed from their color), are distinguished from black powder not only by their appearance, but also by their very slow combustion in open air, by their comparatively gradual and long-sustained action when used in guns, and by the simple character of their products of explosion as compared with those of black powder. As the oxidizing ingredient, saltpeter, is contained in brown or cocoa powder in larger proportion relatively to the oxidizable components, sulphur and charcoal, than in black powder, these become fully oxidized, while the products of explosion of the latter contain, on the other hand, larger proportions of unoxidized material, or only partially oxidized products. Moreover, there is produced upon the explosion of brown powder a relatively very large amount of water vapor, not merely because the finished powder contains a larger proportion of water than black powder, but also because the very slightly charred wood or straw used in the brown powder is much richer in hydrogen than black charcoal, and therefore furnishes by its oxidation a considerable amount of water. The total volume of gas furnished by the brown powder (at 0° C. and 760 mm. barometer) is only about 260 volumes per kilogramme of powder, against 278 volumes furnished by a normal sample of black powder, but the amount of water vapor furnished upon its explosion is about three times that produced from black powder, and this would make the volume of gas and vapor developed by the two powders about equal if the heat of its explosion were the same in the two cases; the actual temperature produced by the explosion of brown powder is, however, somewhat the higher of the two.

Although the smoke produced upon firing a charge of brown powder from a gun appears at first but little different in denseness to that of black powder, it certainly disperses much more rapidly, a difference which is probably due to the speedy absorption, by solution, of the finely divided potassium salts by the large proportion of water vapor distributed throughout the so-called smoke.

This class of powder was substituted with considerable advantage for black powder in guns of comparatively large caliber; nevertheless, it became desirable to attain even slower or more gradual action in the case of the very large charges required for guns of the heaviest calibers, such as those which propel shot of about 2,000 pounds weight. Accordingly, the brown powder has been modified in regard to the proportion of its ingredients to suit these conditions, while, on the other hand, powder intermediate with respect to rapidity of action between black pebble powder and the brown powder has been found more suitable than the former for use in guns of moderately large caliber.

The recent successful adaptation of machine guns and comparatively large quick-firing guns to naval service, more especially for the defense of ships against attack by torpedo boats, etc., has rendered the provision of a powder for use with them, which would produce comparatively little or no smoke, a matter of very considerable importance, inasmuch as the efficiency of such defense must be greatly diminished by the circumstance that, after a very brief use of the guns with black powder, the objects against which their fire is destined to operate become more or less completely hidden from those directing them, by the dense veil of powder smoke produced. Hence much attention has been directed during the last few years to the production of smokeless or nearly smokeless powders for naval use in the above directions. At the same time, the views of many military authorities regarding the importance of dispensing with smoke in land engagements has also created a demand, the apparent urgency of which has been increased by various circumstances, for a smokeless powder suitable for field artillery and small arms.

The properties of ammonium nitrate, of which the products of decomposition by heat are, in addition to water vapor, entirely gaseous, have rendered it a tempting material to work upon in the hands of those who have striven to produce a smokeless powder, but its deliquescent character has been the chief obstacle to its application as a component of a powder agent susceptible of substitution for black powder for service purposes.

A German chemical engineer, F. Gans, conceived that, by incorporating charcoal and saltpeter with a particular proportion of ammonium nitrate, he had produced an explosive material which did not partake of the hygroscopic character common to other ammonium nitrate mixtures, and that, by its explosion, the potassium in the saltpeter formed a volatile combination with nitrogen and hydrogen, a *potassium amide*, so that, although containing nearly half its weight of potassium salt, it would furnish only volatile products. The views of Mr. Gaus regarding the changes which his so-called *amide powder* undergoes upon explosion were not borne out by existing chemical knowledge, while the powder compounded in accordance with his views proved to be by no means smokeless, and was certainly not non-hygroscopic. Mr. Heidemann has, however, been successful, by modifications of Gaus' prescription and by application of his own special experience in powder manufacture, in producing an ammonium nitrate powder possessed of remarkable ballistic properties, furnishing comparatively little smoke, which speedily disperses, and exhibiting the hygroscopic characteristics of ammonium nitrate preparations in a decidedly less degree than any other hitherto prepared. The powder, while yielding a very much larger volume of gas and water vapor than black or brown powder, is considerably slower than the latter; the charge required to produce equal ballistic results is less, while the chamber pressure developed is lower, and the pressures along the chase of the gun are higher, than in the case of brown powder.

The ammonium nitrate powder contains, in its normal, dried condition, more water than even brown powder. It does not exhibit any great tendency to absorb moisture from an ordinarily dry or even a somewhat moist atmosphere, but if the amount of atmospheric moisture approaches saturation, it will rapidly absorb water, and when once the process begins it continues rapidly, the powder masses becoming speedily quite pasty. The charges for quick-firing guns are inclosed in metal cases, in which they are securely sealed up; the powder is, therefore, prevented from absorbing moisture from the external air, but it has been found that if the cartridges are kept for long periods in ships' magazines, in which, from their position relatively to the ships' boilers, the temperature is more or less elevated, sometimes for considerable periods, the expulsion of water from some portions of the powder masses composing the hermetically sealed charge, and its consequent irregular distribution, may give rise to want of uniformity in the action of the powder, and to the occasional development of high pressures. Although, therefore, this ammonium nitrate powder may be regarded as the first successful advance toward the production of a comparatively smokeless artillery powder, it is not uniformly well adapted to the requirements which it should fulfill in naval service.

Attention was first seriously directed to the subject of smokeless powder by the reports received about four years ago of remarkable results stated to have been obtained in France with such a powder for use with the magazine rifle (the Lebel) which was being adapted to military service. These reports were speedily followed by others, descriptive of marvelous velocities obtained with small charges of this powder, or some modifications of it, from guns of very great length. As in the case of melinite, the fabulously destructive effects of which were much vaunted at about the same time, the

secret of the precise nature of the smokeless powder was so well preserved by the French authorities that surmises could only be made on the subject even by those most conversant with these matters. It is now well known, however, that more than one smokeless explosive has succeeded the original powder, the perfection of which was reported to be beyond dispute, and that the material now adopted for use in the Lebel rifle bears, at any rate, great similarity to preparations which have been made the subject of patents in this country, and which are still experimental powders in other countries.

So far as smokelessness is concerned, no material can surpass gun cotton pure and simple; but, even if its rate of combustion in a firearm could be controlled with certainty and uniformity, although only used in very small charges, such as are required for military rifles, its application as a safe and reliable propulsive agent for military and naval use is attended by so many difficulties, that the non-success of the numerous attempts, made in the first twenty-five years of its existence, to apply it in this direction, is not surprising.

Soon after its discovery by Schonbein and Bottger in 1846, endeavors were made to apply gun cotton wool, rammed into cases, as a charge for small arms, but with disastrous results. Subsequently Von Lenk, who made the first practical approach to the regulation of the explosive power of gun cotton, produced small arm cartridges by superposing layers of gun cotton threads, these being closely plaited round a core of wood. Von Lenk's system of regulating the rapidity of burning of gun cotton so as to suit it either for gradual or violent action consists, in fact, in converting coarse or fine, loosely or tightly twisted, threads or rovings of finely carded cotton into the most explosive form of gun cotton, and of arranging these threads or yarns in different ways so as to modify the mechanical condition, *i. e.*, the compactness and extent and distribution of inclosed air spaces, of the mass of gun cotton composed of them. Thus, small arm cartridges were composed, as already stated, of compact layers of tightly plaited, fine gun cotton thread; cannon cartridges were made up of coarse, loose gun cotton yarn wound very compactly upon a core; charges for shells consisted of very loose cylindrical hollow plaits (like lamp wicks), along which fire flashed almost instantaneously, and mining charges were made in the form of a very tightly twisted rope with a hollow core. While the two latter forms of gun cotton always burned with almost instantaneous rapidity in open air, and with highly destructive effects if they were strongly confined, the tightly wound or plaited masses burned slowly in air, and would frequently exert their explosive force so gradually when confined in a firearm as to produce good ballistic results without appreciably destructive effect upon the arm. Occasionally, however, in consequence of some slight unforeseen variation in the compactness of the material, or in the amount and disposition of the air spaces in the mass, very violent action would be produced, showing that this system of regulating the explosive force of gun cotton was quite unreliable.

Misled by the apparently promising nature of the earliest results which Von Lenk obtained, the Austrian government embarked, in 1862, upon a somewhat extensive application of Von Lenk's gun cotton to small arms, and provided several batteries of field guns for the use of this material. The abandonment of these measures for applying a smokeless explosive to military purposes soon followed upon the attainment of unsatisfactory results, and was hastened by the occurrence of a very destructive explosion at gun cotton stores at Simmering, near Vienna, in 1862.

It was at about this time that the attention of the English government, and through them of the lecturer, was directed to the subject of gun cotton, the Austrian government having communicated details regarding improvements in its manufacture accomplished by Von Lenk, and results obtained in the extended experiments which had been carried out on its application to the various purposes above indicated, according to the system devised by that officer. One of the results of the lecturer's researches, subsequently carried on at Woolwich and Waltham Abbey, was his elaboration of the system of manufacture and employment of gun cotton which has been in extensive use at the government works with little if any modification for over eighteen years, and has been copied from us by France, Germany, and other countries. By reducing the partially purified gun cotton fiber to pulp, as in the ordinary process of making paper, then completing its purification when in that condition, and afterward converting the finely divided explosive into highly compressed homogeneous masses of any desired form and size, very important improvements were effected in its stability, its uniformity of composition and action, and its adaptability to practical uses, a great advance being made in the exercise of control over the rapidity of combustion or explosion of the material.

No success had attended the experiments instituted in England with wound cannon cartridges of gun cotton threads made according to Von Lenk's plan; on the other hand, a number of results which at first sight appeared very promising were obtained at Woolwich in 1867-68 with bronze field guns and cartridges built up of compressed gun cotton masses arranged in different ways (with varied spaces, etc.), with the object of regulating the rapidity of explosion of the charge. But although the attainment of high velocities with comparatively small charges of the material, unaccompanied by any indications of injury to the gun, was frequent, it became evident that the fulfillment of the conditions essential to safety to the arm were exceedingly difficult to attain with certainty, and appeared indeed to be altogether beyond absolute control, even in so small a gun as the twelve pounder. Military authorities not being, in those days, alive to the advantages which might accrue from the employment of an entirely smokeless explosive in artillery, the lecturer received no encouragement to persevere with experiments in this direction, and the same was the case with respect to the possible use of a smokeless explosive in military small arms, with which, however, far more promising results had at that time been obtained at Woolwich.

Abel's system of preparing gun cotton was no sooner elaborated than its application to the production of smokeless cartridges for sporting purposes was achieved with considerable success by Messrs. Prentice, of Stowmarket. The first gun cotton cartridge, which found considerable favor with sportsmen, consisted of a roll of felt-like paper composed of gun cotton and ordinary cotton, and produced from a mixture of the pulped materials. Afterward a cylindrical pellet of slightly compressed gun cotton pulp was used, the rapidity of explosion of which was retarded, while it was at the same time protected from absorption of moisture, by impregnation with a small proportion of India rubber. Neither of these cartridges afforded promise of sufficient uniformity of action to fulfill military requirements, but after a series of experiments which the lecturer made with compressed gun cotton arranged in various ways, very promising results were attained, especially with the Martini-Henry rifle and a charge of pellet form, the rapidity of explosion of which was regulated by simple means.

A sporting powder which was nearly smokeless had, in the meantime, been produced by Colonel Schultze, of the Prussian artillery, from wood cut up into very small cube-like fragments, converted into a mild form of nitrocellulose after a preliminary purifying treatment, and impregnated with a small portion of an oxidizing agent. Subsequently the manufacture of the Schultze powder was considerably modified; it was converted into the granular form, and rendered considerably more uniform in character and less hygroscopic, and it then bore considerable resemblance to the E. C. powder, a granulated nitro-cotton powder, produced, in the first instance, at Stowmarket, and consisting of a less highly nitrated cotton than gun cotton (trinitrocellulose), incorporated in the pulped condition with a somewhat considerable proportion of the nitrates of potassium and barium, and converted into grains through the agency of a solvent and a binding material. Both of these powders produced some smoke when fired, though the amount was small in comparison with that from black powder. They did not compete with the latter in regard to accuracy of shooting, when used in arms of precision, but they are interesting as being the forerunners of a variety of so-called smokeless powders, of which gun cotton or nitro-cotton is the basis, and of which those of Johnson and Borland, and of the Smokeless Powder Company, are the most prominent in this country.

In past years, both camphor and liquid solvents, such as acetic ether and acetone for gun cotton, and mixtures of ether and alcohol for nitro-cotton, have been applied to the hardening of the surfaces of compressed masses or granules of those materials, by Von Forster and others, with a view to render them non-porous, and in the E. C. powder manufacture the latter solvent was thus applied to harden the powder granules. In the Johnson-Borland powder, camphor is applied to the same purpose; in smokeless powders of French and German manufacture, acetic ether and acetone have been used, and the solvent has been applied not merely to harden the granules or tablets of the explosive, but also to convert the latter into a homogeneous, horn-like material.

Much mystery has surrounded the nature and origin of the first smokeless powder adopted, apparently with undue haste, by the French government, for use with the Lebel magazine rifle. A few particles of the Vieille powder, or *poudre B*, were seen by the lecturer about two years ago, and very small specimens appear to have fallen into the hands of the German government about that time. They were in the form of small yellowish brown tablets of about 0·07 inch to 0·1 inch square, of the thickness of stout note paper, and had evidently been produced by cutting up thin sheets of the material. They appeared to contain, as an important ingredient, picric acid (the basis of "melinite"), a substance extensively used as a dye, and obtained by the action of picric acid, at a low temperature, upon carbolic and cresylic acid, constituents of coal tar. Originally produced by the action of nitric acid upon indigo, and afterward by similar treatment of Botany Bay gum, it was first known as carbazotic acid, and is one of the earliest of known explosives of organic origin. When sufficiently heated, or when set light to, it burns with a yellow smoky flame, and even very large quantities of it have been known to burn away somewhat fiercely, but without exploding. Under certain conditions, however, and especially if subjected to the action of a powerful detonator, it explodes with very great violence and highly destructive effects, as pointed out by Sprengel in 1873, and recent experiments at Woolwich have shown that it does this even, as in the case of gun cotton, when it contains as much as 15 per cent. of water. It is no longer a secret that picric acid at any rate forms the basis of the much vaunted and mysterious explosive for shells for which the French government were said to have paid a very large sum of money, and the destructive effects of which have been described as nothing less than marvelous. M. Turpin patented, in 1875, the use of picric acid alone as an explosive for shells and for other engines of destruction, and whether or not his claims to be the inventor of melinite are valid, there appears no doubt that his patent in France was the starting point of the development and adoption of that explosive.

The attention thus directed in France to the properties of picric acid appears to have given rise to experiments resulting in its employment as an ingredient of the first smokeless powder (*poudre B*) adopted for the French magazine rifle.

The idea of employing picric acid preparations as explosive agents for propulsive purposes originated with Designolle about twenty years ago, but no useful results attended the experiments with the particular mixtures proposed by him. It is certain that the recent adaptation of that substance in France was of a different character, and that, promising as were the results of the new smokeless powder, of which it formed an ingredient, and of which a counterpart was made the subject of experiments at Woolwich about three years ago, its deficiency in the all-essential quality of stability must have been at any rate one cause of its abandonment in favor of another form of smokeless powder, which there is reason to believe is of more simple character.

In Germany the subject of smokeless powder for small arms and artillery was being steadily pursued in secret, while the sensational reports concerning *poudre B* were spread about in France, and a small arm powder, giving excellent results in regard to ballistic properties and uniformity, was elaborated at the Rottweil Powder Works, and appears to have been adopted into the German service for a time, but its first great promise of success seems to have failed of fulfillment through defects in stability.

Reference has already been made to the conversion of gun cotton (trinitrocellulose) and to mixtures of it with less explosive forms of nitrated cotton (or nitrated cellulose of other description), by the action of solvents, into horn-like materials. These are in the first instance obtained in the form of gelatinous masses, which, prior to the complete evaporation or removal of the solvent, can be pressed or squirted into wires, rods, or tubes, or rolled or spread into sheets; when they have become hardened, they may be cut up into tablets or into strips or pieces of size suitable for conversion into charges or cartridges.

Numerous patents have been secured for the treatment of gun cotton, nitro-cotton, or mixtures of these with other substances, by the methods indicated; but in this direction the German makers of the powder just now referred to seem to have secured priority. Experiments were made about a year and a half ago with powder produced in this way at Woolwich, and the Wetteren Powder Company in Belgium has also manufactured so-called paper powders, or horn-like preparations, of the same kind, which were brought forward as counterparts of the French small arm and artillery smokeless powder.

Mr. Alfred Nobel, to whom the mining world is so largely indebted for the invention of dynamite, and of other very efficient blasting agents of which nitroglycerine is the basis, was the first to apply the latter explosive agent, in conjunction with one of the lower products of nitration of cellulose, to the production of a smokeless powder. The powder bears grest resemblance to one of the most interesting of known violent explosives, also invented by Mr. Nobel, and called by him blasting gelatine, in consequence of its peculiar gelatinous character. When the nitro cotton is impregnated and allowed to digest with nitro-glycerine, it loses its fibrous nature and becomes gelatinized while assimilating the nitro-glycerine, the two substances furnishing a product which has almost the character of a compound. By macerating the nitro-cotton with from seven to ten per cent. of nitro-glycerine and maintaining the mixture warm, the whole soon becomes converted into a plastic material, from which it is very difficult to separate a portion of either of its components. This preparation, and certain modifications of it, have acquired high importance as blasting agents more powerful than dynamite, and possessed of the valuable property that their prolonged immersion in water does not separate from them any appreciable proportion of nitro-glycerine.

In the earlier days of the attempted application of blasting gelatine to military uses, in Austria, when endeavors were there made to render the material less susceptible of accidental explosion in active service (as by the penetration of bullets or shell fragments into transport wagons containing supplies of the explosive), this result was achieved by Colonel Hess by incorporating with the components a small proportion of camphor, a substance which had then, for some time past, played an important part in the technical application of nitro-cotton to the production of the remarkable substitute for ivory, horn, etc., known as xylonite. By incorporating with nitro-glycerine a much larger proportion of nitro-cotton than used in the production of blasting gelatine, and by employing camphor as an agent for promoting the union of the two explosives, as well as, apparently, for deadening the violence or reducing the rapidity of explosion of the product, Mr. Nobel has obtained a material of almost horn-like character, which can be pressed into pellets or rolled into sheets while in the plastic condition, and which compares favorably with the gun cotton preparations of somewhat similar physical character just referred to as regards ballistic properties, stability, and uniformity, besides being almost absolutely smokeless. The retention in its composition of some proportion of the volatile substance camphor, which may gradually be reduced in amount by evaporation, renders this explosive liable to undergo some modification in its ballistic properties in course of time; it is believed that this point has been dealt with by Mr. Nobel, and accounts from Italy speak favorably of the results of trials of his powder in small arms, while Mr. Krupp is reported to be carrying on experiments with it in guns of several calibers.

The government committee on explosives, in endeavoring to remedy the above defect of Nobel's original powder, were led by their researches to the preparation of other varieties of nitro-glycerine powder, which, when applied in the form of wires or rods, made up into sheaves or bundles, have given, in the service small bore rifle, excellent ballistic results. The most promising of them, which fulfills, besides, the conditions of smokelessness and of stability, so far as can be guaranteed by the application of special tests of exposure to elevated temperatures, etc., is now being submitted to searching experiments with the view of so applying it in the arm as to overcome certain difficulties attending the employment, in a very small bore rifle, of an explosive developing much greater energy than the black powder charge, which therefore gives very considerably higher velocities even with much smaller charges, and consequently heats the arm much more. Thus, the service black powder charge furnishes, with the small bore rifle, an average (and variable) velocity of 1,800 f. s., together with pressures ranging from 18 to 20 tons per square inch; on the other hand, with considerably less of the powder referred to, there is no difficulty in securing a very uniform velocity of about 2,200 f. s. with pressures not exceeding 17 tons, while velocities as high as 2,500 f. s. are obtainable with pressures not greater than the maximum allowed with the black powder charge.

It is obvious, from what has already been said respecting the causes of the erosive action of powder in guns, that comparatively considerable erosive effects would be expected to be produced by powders of high energy as compared with black powder. Moreover, the freedom of the products of explosion from any solid substances, and consequently the absence of any fouling or deposition of refuse in the arm, causes the heated surfaces of the projectile and of the interior of the barrel to remain clean, and in a condition, therefore, very favorable to close adherence together. If to these circumstances be added the fact that the behavior of the smokeless powder has to be adapted to suit an arm, a cartridge, and a projectile originally designed for use with black powder, it will be understood that the devising of an explosive which shall be practically smokeless, sufficiently stable, and susceptible of per-

fectly safe use in the arm under all service conditions, easy of manufacture, and not too costly, is, after all, but a small part of the difficult problem of adapting a smokeless powder successfully to the new military rifle —a problem which, however, appears to be on the near approach to satisfactory solution.

The experience already acquired in guns ranging in caliber from 1·85 inches to 6 inches, with the smokeless powder devised for use in our service, has been very promising, and indicates that the difficulties attending its adaptation to guns designed for black powder are likely to prove considerably less than in the case of the small arm. But here, again, the circumstances that much smaller charges are required to furnish the same ballistics as the service black powder charges, and that the comparatively gradual and sustained action of the new powder gives rise to lower pressures in the chamber of the gun and higher pressures along the chase, demonstrate that the full utilization of the ballistic advantages, and the increase in the power of guns of a given caliber and weight with the new form of powder, are only attainable by some modifications in the designs of the guns—such as a reduction in size of the charge chamber, and some additions to the strength, and, perhaps, in some cases, of the length, of the chase.

When, however, the smokeless powder has been adapted with success in all respects to artillery, from small machine guns to guns of comparatively heavy caliber, and when its ballistic advantages have been fully utilized in guns of suitable design, it will remain to be determined how far such a powder—undeniably of much more sensitive constitution than black powder or any of its modifications—will withstand, unchanged and unharmed, the various vicissitudes of climate and the service storage conditions in ships and on land in all parts of the world—a condition essential to its adaptability to naval and military use, and especially to the service of our empire; and whether sufficient confidence can be placed in its stability for long periods under these extremely varied conditions to warrant the necessary freedom from apprehension of possible danger, emanating from within the material itself, to allow of its being substituted for black powder wherever its use may present advantages.

Possibly it might be that the storage, with perfect safety, of such a powder in ships, forts, or magazines might demand the adoption of precautionary measures tending to place comparatively narrow limits upon the extent of its practicable service applications; even then, however, an imperative need for the introduction of special arrangements to secure safety and immunity from deterioration may be of small importance as compared with the great advantages which the provision of a thoroughly efficient smokeless powder may secure to the possessor of it, especially in naval warfare.

That the opinions respecting the importance of such advantages are founded upon a sound basis one can hardly doubt after the views expressed by several of the highest military and naval authorities, although opinions as to their extent may differ very considerably even among such authorities.

The accounts furnished from time to time from official and private sources of the effects observed, at some considerable distance, by witnesses of practice with the smokeless powders successively adopted in France, have doubtless been regarded by military authorities as warranting the belief that the employment of such powders must effect a great revolution in the conduct of campaigns. Not only have the absence of smoke and flame been dwelt upon as important factors in such a revolution, but the recorders of the achievements of smokeless powder—whose descriptions have doubtless been to some extent influenced by the vivid pictures already presented to them of what they *should* anticipate—have even been led to make such explicit assertions as to the *noiselessness* of these powders, that high military authorities have actually been thereby misled to portray, by vivid word painting, the contrast between the battles of the future and the past; to imagine the terrific din caused by the discharge of several hundred field guns and the roar of musketry in the great battles of the past, giving place to noise so slight that distant troops will no longer receive indications where their comrades are engaged, while sentries and advanced posts will no longer be able to warn the main body of the approach of an enemy by the discharge of their rifles, and that battles might possibly be raging within a few miles of columns on the march without the fact becoming at once apparent to them.

It is somewhat difficult to conceive that, in these comparatively enlightened days—an acquaintance with the first principles of physical science having for many years past constituted a preliminary condition of admission to the training establishments of the future warrior—the physical impossibility of such fairy tales as appear to be considered necessary in France for the delusion of the ordinary public would not at once have been obvious. Yet, even in professional publications in Germany, where we are led to expect that the judgment of experts would be comparatively unlikely to be led astray through lack of scientific knowledge, we have, during the earlier part of last year, read, in articles upon the influence of smokeless powder upon the art of war (based evidently upon the reports received from France) such passages as these: "The art of war gains in no way as far as simplicity is concerned; on the contrary, it appears to us that the absence of so important a mechanical means of help as *noise* and smoke were to the commander requires increased skill and circumspection in addition to the qualities demanded by a general. . . . The course of a fight will certainly be mysterious, on account of the *relative stillness* with which it will be carried on."

In an amusing article, in imitation of the account of the battle of Dorking, which appeared in the *Deutsche Heeres Zeitung* of April last, the consternation is described with which a battalion receives the information from a wounded fugitive from the outposts that the enemy's bullets have been playing havoc among them, without any visible or audible indications as to the quarter of attack. Later in the year, and especially since the maneuvers before the German and Austrian emperors, when the employment of the new smokeless powder was the event of the day, the absurdity of the assertions as to the noiselessness of the new powders became a theme for strong observations in the German service papers; the assumed existence of a noiseless powder was ridiculed as a thing equally impossible with a recoilless powder; the violence of the report, or explosion, produced upon the discharge of a firearm being in direct relation to the volume and tension of the gaseous matter projected into the surrounding air.

The circumstance that blank ammunition was alone used in the smokeless powder exhibition at the German maneuvers may have served to lend some support to the assertions as to comparatively little noise made by the powder—the report of blank cartridges being slight on account of the small and lightly confined charges used. It is said that the sound of practice with blank ammunition at the German maneuvers was scarcely recognized at a distance of 100 meters. In a recently published pamphlet on the results of employment of the latest German smokeless powder in the maneuvers it is stated, on the other hand, that the difference between the violence of the report of the new powder and of black powder is scarcely perceptible; that it is sharper and more ringing, but not of such long duration. This description accords exactly with our own experience of the reports produced by different varieties of smokeless powder, and of the lecturer's earlier experience with gun cotton charges fired from rifles and field guns. The noise produced by the latter was decidedly more ringing and distressing to the ear in close proximity to the gun, but also of decidedly less volume than the report of a black powder charge, when heard at a considerable distance from the gun.

As regards smokelessness the present German service powder is not actually smokeless, but produces a thin, almost transparent, bluish cloud, which is immediately dissipated. Independent rifle firing was not rendered visible by the smoke produced at a distance of 300 meters, and at shorter ranges the smoke presented the appearance of a puff from a cigar. The most rapid salvo firing during the operations near Spandau did not have the effect of obscuring those firing from distant observers.

That in future warfare, if smokeless or nearly smokeless powders have maintained their position as safe and reliable propelling agents for small arms and field artillery, belligerents of both sides will be alike users of them, there can be no doubt. The consequent absence of the screening effect of smoke—which on the one hand removes an important protection and the means of making rapid advances or sudden changes of position in comparative safety, and on the other hand secures to both sides the power of insuring to the fullest extent accuracy of shooting, and of making deadly attack by individual fire through the medium of cover, with comparative immunity from detection—can scarcely fail to change more or less radically many of the existing conditions under which engagements are fought.

As regards the naval service, it is especially and, at present at any rate, exclusively for the new machine and quick-firing guns that a smokeless powder is wanted; for such service the advantages which would be secured by the provision of a reliable powder of this kind can scarcely be overestimated, and their realization within no distant period may, it is believed, be anticipated with confidence.

A SENSITIVE TEST FOR CERTAIN IMPURITIES IN MERCURY.

By Dr. G. GORE, F.R.S.

VARIOUS investigators, including Wheatstone, Jules Regnault, Gaugain, Crova, Robb, Lindeck, and Hockin and Taylor (*Journal Telegraph Engineers*, 1879), have examined the electro-motive forces of metallic amalgams in acid and saline liquids, and the latter investigators have shown that 1 part by weight of zinc in 23·6 million parts of mercury is electro-positive to pure mercury in a solution of zinc sulphate.

My object in the present research was different from those of previous investigators, and was briefly to ascertain and illustrate the degree of delicacy of the voltaic energy method when employed as a means of detecting the presence of certain metals in mercury.

Two portions of very pure mercury in an electrolyte were connected by insulated platinum wires with an ordinary astatic torsion galvanometer of 100 ohms resistance, and a sufficiently minute proportion of a very dilute amalgam, of known strength, of one of the particular metals with some of the same mercury was added to one of the portions of mercury, to cause the needles of the instrument to be just visibly deflected while being viewed with the aid of a magnifying glass. The volume of water employed in each electrolyte was 120 c. c. The following table shows the results:

One part of	1·0 grain of HCl or H_2SO_4 in 120 c. c. of water. Parts of mercury.	10 grains of KCl in 120 c. c. of water. Parts of mercury.
Mg	110,274,000,000	13,430,858,806
Zn	104,950,000,000	18,034,482,758
Cd	184,828,432	10,404,225
Sn	38,900,000	8,831,632
Cu	15,484,375	1,640,160
Bi	9,762,300	1,621,000
Pb	5,651,149	1,050,341
Ag	905	79

The minimum degree of electro-motive force required to visibly move the needles was found by heating one end of a single thermo-electric couple of iron and pure copper 9·6 Centigrade degrees higher than the other end, or of one of platinum and copper 49·3° C. higher than the other, the opposite ends of the couples being immersed in vessels of oil, and was in each case equal to about 0·00013258 volt. This, therefore, was approximately the degree of electro-motive force of an amalgam of 1 part of zinc dissolved in about 105,000 million parts of mercury, or of 1 part of magnesium in about 110,000 million parts of mercury, when opposed to pure mercury in solutions at atmospheric temperature of sulphuric or hydrochloric acid of the degrees of strength given. With the aid of a much more sensitive galvanometer, the influence of very much smaller proportions of impurity upon the amounts of voltaic energy and electro-motive force might be detected.

In the above table the order of voltaic energy of the metals is substantially the same as that of the metals alone and unamalgamated. With each amalgam the amount of energy gradually declined, but recovered on stirring the mixture. The decline was quickest with the most dilute ones. An amalgam of magnesium with 1,605 times its weight of mercury rapidly became covered with a thin film of black suboxide of magnesium on exposure to the air.

As the influence of the above minute proportions of all the metals, except silver, may be thus readily detected, I have employed this method to test the purity of mercury. I took about 2,000 grains of mercury, containing, dissolved in it, 6 grains of a mixture of the above eight metals, distilled off the mercury, and then used the product in place of the amalgam in the potassium chloride solution in the above manner. The galvanometer needles were very slightly affected, but after a second distillation of the mercury the needles were not visibly moved.—*Chem. News.*

MILK OF THE BOTTLE-NOSE WHALE.

(*Globiocephalus Melas.*)

By Prof. PERCY F. FRANKLAND, Ph.D., and FRED. J. HAMBLY, Assistant Lecturer on Chemistry in University College, Dundee.

ON the occasion of the recent capture of no less than 160 individuals of this species in Tankerness Bay, near Kirkwall, Orkney, our colleague, Prof. D'Arcy Thompson, received, among other specimens, a small quantity of the milk of one of these creatures, the liquid having been scooped directly from the mammary gland after death.

The sample was, unfortunately, a very small one (but little in excess of 3 grammes), which is the more to be regretted as an almost unlimited quantity must have been available for collection, a large number of the captured whales being females.

The milk presented a thick, creamy appearance, globules of fat being clearly discernible in the mass, which was possessed of a strong fishy odor.

Owing to the small quantity of material at our disposal, we were unable to make an exhaustive analysis, but such determinations as were possible we deemed it advisable to perform in duplicate, although, from the non-homogeneous nature of the substance, it was not to be anticipated that very concordant results would be obtained.

The following are the results of the duplicate analyses:

	No. 1. Grammes.	No. 2. Grammes.
Weight of milk taken	1·431	1·678

RESULTS OF ANALYSES EXPRESSED IN PARTS PER 100.

			Mean.
Total solids (dried at 100—105° C.)	52·13	50·53	51·33
Water	47·87	49·47	48·67
Non-fatty solids (insoluble in ether)	7·72	7·42	7·57
Fat (soluble in ether)	44·41	43·11	43·76
Ash	0·44	0·47	0·46

That the discrepancies between the two analyses were due to want of homogeneity in the sample, and not to any inaccuracy in the determinations, is clearly shown by the fact that the total solids, non-fatty solids, and fat stand in the same proportion to each other in both analyses. Thus, sample No. 2 was apparently more aqueous than No. 1, and if the results of No. 2 be corrected in the ratio of 50·53 : 52·13, then the figures of the analysis No. 2 become practically identical with those of No. 1; thus, the non-fatty solids become 7·65 per cent. and the fat 44·45 per cent.

The milk of this species of the bottle-nosed whale is thus enormously rich in fat, while the non-fatty ingredients are rather below than above the average of those present in the milk of ordinary mammals. The only other analysis of the milk of a *Cetacean* with which we are acquainted is that made by Prof. Purdie, of St. Andrews, of the milk of the porpoise, and which yielded the following very similar results (*Brit. Assoc. Report*, 1885, Aberdeen):

	Per cent.
Total solids	58·89
Water	41·11
Non-fatty solids	13·09
Albuminoids	11·19
Milk sugar (?)	1·33
Fat	45·80
Mineral matter	0·57

The table below exhibits the composition of the milk of some of the commoner mammals.

AVERAGE PERCENTAGE COMPOSITION, BY WEIGHT, OF MILK FROM VARIOUS MAMMALS (HOPPE-SEYLER).

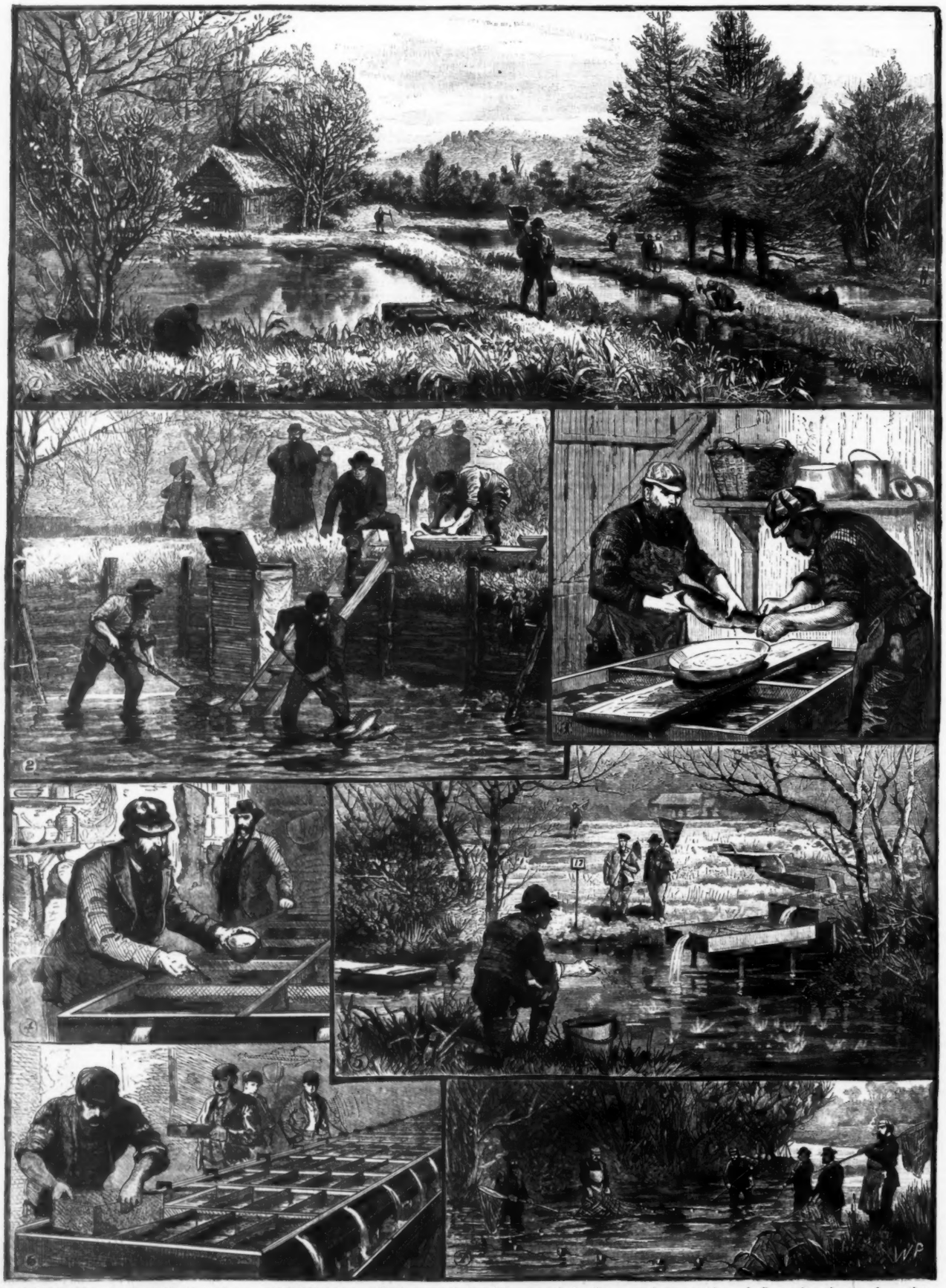
	Woman.	Cow (ammoner.)	Ewe.	Mare.	Bitch (meat-fed).	Sow.	Ass.	Buffalo.	Camel.	Hippopotamus.
Water	87·24	86·48	83·30	91·15	71·21	81·80	89·01	80·64	86·34	90·43
Total solids	12·75	13·52	16·70	8·85	28·79	18·20	10·99	19·36	13·66	9·57
Casein	1·90	3·84	5·80	1·05	12·89	5·30	3·57	5·55	3·67	....
Fat	4·32	4·01	6·15	1·27	12·04	6·00	1·85	8·45	2·90	4·54
Sugar	5·97	4·93	3·96	5·75	1·82	6·07	5·05	4·52	5·78	....
Salts	0·28	0·74	0·66	0·37	1·63	0·83	0·52	0·84	0·66	0·11

We examined the ash of the whale's milk qualitatively, and found that it contained a large proportion of phosphoric acid. We also saponified the fat, and on treating the aqueous solution of the resulting soap with ether we obtained a small quantity of extract, which was, however, insufficient for further examination. On decomposing the soap with dilute sulphuric acid the resulting product proved to be only partially soluble in cold alcohol, a residue melting at 51 deg. C. being left. This may possibly be spermaceti (m. p. 49 deg. C.), which had escaped saponification, for, as is well known, it is only saponified very slowly. We were, unfortunately, unable to further investigate this interesting point, owing to the material being exhausted.—*Chem. News.*

THE belief that smoke from soft coal may have beneficial sanitary effects is gaining ground. It is claimed that sulphur in the coal when burned becomes highly disinfectant. Further, that creosote and its allied products are thrown off with the fumes of bituminous coal, and that an atmosphere charged with carbonic acid must be freer from germs of disease than an apparently purer air.

FISH BREEDING: A SURREY TROUT FARM.

THE artificial culture of trout and salmon is largely practiced at several establishments in Great Britain—at Howietoun, near Stirling, by Sir James Maitland; by Mr. Armistead, at Dumfries; at Malvern, in the Midland Counties Fish Culture Establishment, founded by the late Mr. William Bargess; and by Mr. Thomas Andrews, of Westgate House, High Street, Guildford, who is in occupation of many breeding ponds amid the noble range of hills on the southern border of Surrey, adjacent to Hampshire and Surrey, in the neighborhood of Haslemere. In the grounds behind his residence at Guildford, where the river Wey flows at the bottom of his garden, he has converted what was formerly a greenhouse into a commodious and well arranged hatching house, to which the ova are brought from his ponds. During the past twenty-three years Mr. Andrews has successfully carried on his piscicultural operations, producing more than fifty millions of trout, American char, and grayling, which he supplies, in ova, fry, or yearlings, to rivers in every part of the United Kingdom, also sending the impregnated ova to Australia, Ceylon, America, Italy, Spain, France, Belgium, and other foreign countries. The anglers of Hampshire, Kent, and all the southern counties of England are much indebted to Mr. Andrews for his assistance in stocking



1. Fish-breeding ponds of Mr. T. Andrews, at Hind Head, near Haslemere. 2. Catching the fish for the spawning operation. 3. Squeezing the ova from the female fish. 4. Adding the milt to the ova in the hatching house. 5. Feeding the fish. 6. Operations in the hatching house at Guildford. 7. Netting a pond or stream.

FISH BREEDING—A SURREY TROUT FARM.

their rivers. Upward of two millions and a half of ova are annually laid down at Guildford, and are sent, in specially constructed packing boxes, to all parts of the world.

On the "trout farm," of about eight acres, situated on the southern slope of the well known hill called Hind Head, near Haslemere, 350 ft. above the sea level, Mr. Andrews has twenty ponds, fed by nearly a hundred springs. They form a compact series, part of which is shown in our illustrations. The natural fall of the ground admits of ponds on eight different levels. At the time our artist visited these ponds, the water of one of them was being drawn off, for the purpose of catching the fish for the spawning operation. When all the fish were collected, removed to the "spawning shed," and examined, they were operated upon by Mr. Andrews and his assistants. The fish are gently handled, in the position shown in the sketch, and the ova are taken from the female fish. The milt from the male fish is afterward added. After being thoroughly washed of all impurities the eggs are placed in cans, and taken to the hatchery at Guildford. Two of our sketches show the manipulation in the hatching house.

The collecting of ova necessitates much exposure to wet and cold, occurring as it does in the winter months, although much of the spawning is done under cover of the shed at the ponds. The fingers are sometimes so benumbed, after handling 500 or 600 fish, that one has been unable to take a watch out of his own pocket.

Mr. Andrews has numerous other ponds in the vicinity, but the arrangement of this series will strike any one having a knowledge of fish culture as being of the very greatest advantage. Some of these ponds contain yearling trout and grayling of four to seven inches; others two-year-olds, from seven to twelve inches; and some hold still larger fish, the favorite varieties of *Salmonidæ* being *S. fario*, *S. levenensis*, *S. fontinalis*, and grayling. The Loch Leven trout, crossed with the English trout, produce a fine artificial variety. The American char, *S. fontinalis*, is also highly appreciated. Mr. Andrews has carefully studied the improvement of breeds of fish.

The natural kinds of food for trout—namely, *Limnæ* (snails) and *Gammarus pulex* (fresh water shrimp)—are cultivated here in vast quantities. Mr. Andrews attributes the rapid growth and development of his fish to the suitability of the water and to judicious feeding, every fish coming out perfectly clean, with no sign of parasite or fungus. There is much to be looked after all the year round, if the fish are to be brought to maturity, as they have numerous enemies both in the water and in the air.

A very pretty sight is feeding the fish. As soon as the first handful of food is thrown into the ponds, the fish rush from all points in thousands, and, in the height of the feeding season, one would get fairly wet, if standing on the edge of the pond, from the splashing of these spotted beauties, many of which weigh from 5 lb. to 8 lb. each. The large fish are fed daily upon horse flesh, boiled and ground up; the smaller fish upon raw liver, in addition to the natural food in the water, but these require very little artificial food.—*Illustrated London News.*

[FROM THE CINCINNATI INQUIRER.]

HOW CIRCUS PERFORMERS LEARN TO GO BARE BACK.

TRAINING women and men to ride bare back in the circus arena is a business. Cincinnati has such a training school, and it has turned out some of the greatest bare back, hurdle, all-around, somersault, trick riders, and two and four and six horse riders that the American continent has ever seen. The casual observer has little idea of the patience and fearlessness, hours of hard unceasing labor that a rider in the circus arena must go through before proficiency is attained.

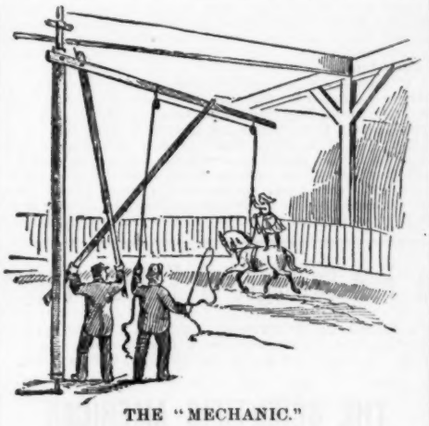
Recently a reporter spent several hours watching the exercises and noting the peculiarities of the training. Mr. John Wilson, the veteran four-horse rider, is at present in charge of the establishment, and spends eight hours every day in practicing the candidates for excellence in the sawdust arena for the John Robinson shows. The training school is on John Street, near Poplar, where the winter quarters of the late John Robinson's shows have been for many years. The building for the school is of brick, two stories high, and was erected for the purpose in 1865. It is a barn-like structure, with an office and a room which serves as a dressing room for the women as well as a storeroom for various styles of bridles, bits, and horse medicine. Alongside the office are fifteen newly painted circus wagons, and opposite twelve valuable horses stand in their stalls. Bales of hay are piled up all round, and in the rear of the building is the ring, which is 42 ft. in diameter. A horse going around it forty-four times would cover a mile. Formerly a board ring was used, and broken wrists, fractured legs, and dislocated arms were the too frequent result. There are about eighteen inches of tanbark in the ring, covered with from eight to twelve inches of sand and sawdust. The ring is soft, and yet springy, and absolutely free from dust.

In the center of the ring is a six inch pole reaching to a strong joist that is one of the roof supports. This pole revolves, and, at a distance of twelve feet from the ground, has an arm extending to the circumference of the ring. To this arm are attached two pulleys, and over them runs a rope, one end of which is attached to a ring in the rider's back and the other end of which Mr. Wilson, the trainer, holds tightly wound around his left hand, while in his right hand he holds a long whip, which as the horse lags he snaps with a crack, to let the animal know there will be no monkey business.

The machine or contrivance is known as a "mechanic," and its object is to prevent the learner from falling. There is a wide strap, which the new riders fasten around their waists or under the shoulders, in the back of which is an iron ring. In case of falling or slipping the rider is held up, while the horse passes on. For women, however, the arrangement is more complicated. Two straps pass over the shoulders, and the ring is set at the back of the neck, attached to a strap running from the waistband to the rope that runs over the pulleys and into the trainer's hands holding the learner in case of a fall erect in the air, her feet dangling and the horse passing from under her. The trainer continually moves around the pole with the horse, watching every motion of the animal's head and every swish of the long tail, as when the ears go back and the tail swishes the animal is going to kick, and he is at once spoken to and held up. Thus if a horse is going to kick, which the trainer at once knows, he can reverse the mechanic and hold the rider aloft in the air completely out of danger.

The first horse that came into the ring was a six year old gelding of Arabian stock, which had never been before an assemblage and was a stranger to the plaudits of the arena. He had on a bitting machine, consisting of a wide girdle over the back just behind the shoulders, in which were the hand pieces to assist the rider in vaulting on and off. A rubber bit was used, and the curb held the horse's head in a firm and graceful attitude.

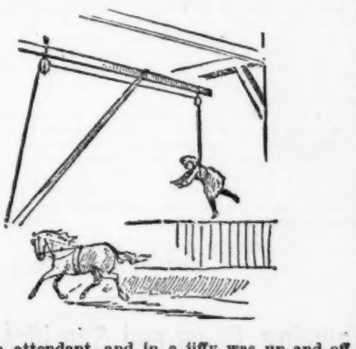
"The horse had been a kicker," said Will Darr, a stout-built, athletic young man of 28, with a cigar



THE "MECHANIC."

stump in his mouth, clad in a pair of trousers, woolen shirt, and in his stocking feet. Vaulting to the nag's broad back, the animal loped around the ring. Then Darr got on his knees, next stood upright, balancing himself on the horse's back, while with his left hand he held the cord that ran over the pulleys of the mechanic. Now on one foot, now on the other, he danced back and forth with motion of the horse, while in his right hand he held the reins. All the time he spoke to the horse: "Good boy! good boy! good man!" The young man was an expert rider and has been two years in the ring. He was as much at home on the horse's back as most people are on terra firma. Half an hour's practice sufficed for this horse. Mrs. Marks, a compactly built, gracefully formed woman, clad in gray flannel skirt to her knees, gray flannel knee breeches, and striped blue stockings, next entered the arena. Her feet were incased in opera slippers, and she wore a tight-fitting basque. She was also an expert rider and perfectly at home on the horse. She stood on one foot, then on both, walking backward and forward on the horse's broad back as easily and as gracefully as though on a parlor carpet. She stood perfectly erect, then jumped up eighteen inches or two feet, alighting steadily on the horse's rump; then turned with her face to the horse's tail, and at last came down in a finish. The horse was of Norman breed, with back and rump very broad. Resting for perhaps five minutes, the horse slowly walking around the ring, she chatted with the ring master and then started in again. For a time she sat upon the horse, working her body all over his back and accustoming the animal to every change of position. This horse is called John and is valued at $1,500.

A plump young woman of eighteen years, who formerly worked on the trapeze, was next. She had only been riding four days, and was training for the hurdle races and the Roman chariot hippodrome races. She seemed perfectly fearless, and mounted with the



aid of an attendant, and in a jiffy was up and off. She was training to do the vaulting act, where the horse leaps over a bar gate or a hurdle, and rider dismounts and vaults on again after the horse has cleared the hurdle.

"Now, down!" shouted Johnny Wilson after she had ridden around several times. Grasping the handles around surcingle, she gracefully leaped to the ground, and Wilson gently pulling the rope that was attached to the ring back of her neck, she vaulted back again. This was repeated until she at last vaulted without the aid of the rope. The exercise was violent, and her cheeks glowed with a flush of health, giving a roseate tint to her fair complexion that would have put to blush any painted carmine stage beauty that ever trod the boards. The horse kept on the lope, Wilson cracked his whip, the rings and chains rattled and cracked, the horse puffed and panted, and the young lady rose to her knees and then on both feet. "Bear on your toes!" shouted Wilson. Crack went the whip. "Walk up and down!" "All over the horse!" "Bully for you!" "Toes down!" "Outside shoulder in more!" "Stay there!" "Watch your toes!" were the quick, short orders that came in rapid succession between the cracks of the whip and pants of the horse.

"My knees are giving out," at last she said.

"All right; come down," responded Wilson, and the lady was seated on the horse's rump. Such was Miss Sallie Cramer, who enters the arena next season as a hurdle rider, and pockets her snug little salary of $45 a week.

"The hardest thing to teach the ladies," said Johnny Wilson, "is jumping on the horse—dancing on him. There is also a good deal of trouble in teaching beginners their proper positions. You see they must stand erect. Robinson's method was to first teach all his pupils to stand correctly on the horse. What is to stand correctly? When the head is erect, heels together, knees straight and toes out, the right shoulder turned in facing the horse. They must get the spring from the ball of the foot, and not from the knees. The tendency is to ride on the heel, and that is what we have to overcome in all new riders. That is why you hear me continually shouting: 'Keep your toes into the horse.' When a lady first begins to ride the tendency is to scrouch, as if to grab the horse by the mane, and all that has to be overcome."

The five minutes' rest being over, Miss Sallie signified her willingness to finish out her half hour, and the horse broke into the lope. This differs from the canter, in that both the inside feet of the horse—that is, the front and hind foot toward the ring master—are in the air at once, while every muscle in the horse's body seems to be in motion. As she stood up, holding the rope in her left hand and the reins in her right, whisking around the ring, now on one foot, now on the other, Wilson kept shouting in a melodious monotone: "Keep on your toes." "Keep on your toes," "Walk all around on 'em," "Don't lean back on 'em," "Stand up straight," "That's good," "Hold on to your skirt," "There, take hold of the rope," "Pull up your rein," "Balance yourself."

Suddenly a slip was made, but not a fall. Wilson quickly pulled the cord, and dangling in the air perfectly unconcerned the lady hung, while the horse cantered unconcernedly on. It was the work of a moment to let her easily down into the ring, and as the horse came around she vaulted on to his back again.

"She is going to make a great rider," remarked Wilson, "for she has not the slightest fear of the horse," and after her ride was over she repaired to the dressing room and soon came out in a blue dress, and joining Wilson at the pole, walked around by his side, watching every order and studying the horse's motions as the other riders went through their exercises.

Thomas B. Hughes, training for the hippodrome and as a four-horse rider, came out clad in stockinet tights and a red jockey cap. His horse was a half brother to an Arabian horse. He rode around several times barebacked, and then moved all over the animal's back, so that no amount of tickling would make him kick, saying all the time, "Steady, boy." Then he stood up, jumped up, jumped up and down and turned about with his face to the animal's tail. He was a splendid specimen of a man physically, muscular and agile, tall, with no surplus flesh, his motions graceful, self-possessed and easy. The horses at the training quarters include Menenger, a jumping horse, who jumps over seven horses, and is so well trained and easily handled that a lady, Miss Mabel Read, manages him. There are four Norman horses, with broad backs, large and strong limbed, perfectly gentle and tractable, and all white or dapple gray. They are known as John, Charley, Don, and Dick; Hiram is a Grey Eagle; Lucy, a sorrel mare of Glencoe stock, blooded; Prince, a large, fine broncho pony, broke for a lady or gentleman in the hurdles. There is also a span of black mares, for Roman races in the hippodrome. They are of Morgan stock, and small, chunky horses, and the two that run against them are a pair of thoroughbred bays, Ellen Tree and Harry.

TESTS OF VISION.

MR. BRUDENELL CARTER read a paper the other evening before the Society of Arts, in London, on "Vision Testing for Practical Purposes," in the course of which he said that satisfactory vision depends upon two distinct elements, viz., the power of seeing the shape or outline of an object and the power of seeing its color, and the two must be considered separately.

Describing the background of the eye as an infinitely fine mosaic composed of the terminations of sensitive nerve fibers, each with independent sensibility, Mr. Carter compared the conveyance of impressions to the brain with the conveyance of impressions by the sense of touch from one finger tip and then from five finger tips. In the latter case we combine the impressions without analyzing them, and so we do the impressions made upon the nerve fibers of the eye. Each isolated fiber is circular; but closely packed, the fibers become hexagonal. According to distance, the retinal image of the same object may fall upon one or upon several hexagons, or even upon a fraction of one. If the object is a dark spot, the affected hexagon receives less illumination; if a bright spot, more. The amount of difference must reach a certain degree before any given eye can recognize a dark spot or a bright one; and some eyes have a greater or less degree of light perception than others. Thus, one person sees a particular star before it is visible to another. Arago met with a Siberian Tartar who with the unaided eye could see the third satellite of Jupiter, which has probably never been so seen by any European. This is acuteness of light perception; and in order to arrive at acuteness of vision it is necessary to ascertain the power of the person tested to see separateness—that is, to see whether a certain bright or dark object is single or multiple, composed of a single spot or of two or more spots.

The most accurate test is obtained by using groups of spots under certain conditions. It has been necessary to set up a standard which is fairly expressive of average human capacity. Its requirements are fulfilled when a man counts correctly the spots in certain groups at distances respectively of 50, 25, and 10 meters, the magnitude of the retinal image being the same in all cases. Printed types answer fairly well for many purposes, but they are inferior to groups of spots, which correspond with the anatomical structure of the retina. The dots used in the army are imperfect contrivances,

and do not afford trustworthy results. The best testing arrangement is a revolving wheel with groups of dots on the margin behind a disk with apertures which disclose one group at a time.

At a certain distance to be fixed, a person with normal vision gives the number of dots correctly and rapidly. If mistakes are made, the distance is reduced until accuracy is obtained, and the vision is a fraction of the normal corresponding with the distance. The normal vision as thus defined is for the average man the practical limit of human faculty. The ophthalmic expert declares when the limit is attained. The railway expert must say what the standard is to be, and whether half or three-fifths of normal vision can be accepted. The day signal may be seen at the greatest distance at which it is visible, or at three-fifths of it, or at half the distance. In the latter cases time would be lost in putting on brakes to avoid collisions; but still the time left might be sufficient.

If a man has less than normal vision, the expert has to determine the cause of the defect, whether it be defective action of the nerve, or turbidity where there ought to be transparency—conditions remediable, if at all, only by medical or surgical treatment; or whether it be faults of shape or curvature, often remediable by glasses. The railway expert must decide whether men may wear glasses, which may be clouded by rain or spray, or broken, lost, or forgotten. In the army, commissions are not given to candidates whose vision falls below one-sixth of the normal. If workmen with good vision are plentiful, men with defective vision must be heavily handicapped.

Astigmatism, if uncorrected by glasses, would be dangerous in an engine driver, because he might see a signal post and yet not see the horizontal arm. For night signals we must use colored lights, generally green and red, and unfortunately 4 per cent. of workingmen have imperfect color vision. The power of seeing light depends upon the communication of its wave movement to the fibers of the optic nerve. Just as a tuning fork or tuned string or the human ear will only respond to or be influenced by rates of vibration with which they are in unison, so differences exist between different eyes with regard to light, and some persons see more or less red and some more or less violet than is usually visible. The red end of the spectrum appears shorter to some than to others; that is, the slowest and longest waves fail to call some nerve fibers into corresponding vibration, just as some ears fail to catch the deepest notes which are audible to others.

Going a little further, there is incapacity to respond, not only to pure red, but also to the red waves, the characters of which have been modified by some admixture of green. A so-called "red blind" person, in looking at the spectrum, if it were anywhere of pure red, would not see that portion, but would see only the surface of the screen on which the spectrum was thrown as if the spectrum were not there. Looking at the red lamp of a train, he would see it by virtue of the green rays which the glass would suffer to pass. A "green blind" person would not lose sight of a lamp with a green glass, but he would see its luminosity by virtue of the color other than pure green which it transmitted. There are only a few persons who are violet blind.

The worst possible test is that used on many railways. A candidate looks at actual signals, and is asked to say which is red and which is green, or which means "Stop," and which "Go ahead." The test is useless, because the red lamp is not invisible to the red blind nor the green lamp to the green blind. Each is seen as a light of small luminosity by virtue of the rays other than red or green which it transmits. The candidate will know this to start with, and, having made a correct guess, that will keep him right, because the two lights look different. We require to eliminate the even chance and the apparent difference of luminosity. Driving an engine at great speed, a man may see a red signal which, either from a defect in the lamp or from atmospheric conditions, may not seem to be bright, and, taking it for green, he will rush into danger which he ought to avoid. It is not enough that on a given occasion a candidate does not fall into a mistake between two colors; it is necessary to see that he cannot fall into one. This condition will only be fulfilled if his optic nerves possess the natural power of vibrating in response to each of the three primary colors of the spectrum, and, by natural consequence, in response also to their innumerable derivatives. It was to accomplish this object that Prof. Holmgren devised his famous test with colored wools; and, as the object of this is to ascertain whether a person sees colors correctly, not to ascertain whether he names them correctly, the element of naming is carefully kept out of account. If we are once certain that a person can see the difference between red and green, there cannot be the slightest difficulty in teaching him the right name of each, even supposing that he did not know it before; but the knowledge of the names is absolutely useless as long as there exists any liability to confuse the things. Holmgren's test carried out in rigid conformity to his instructions has now been applied by skilled observers to young and adult males in almost every civilized country; and Dr. Joy Jeffries, in the last edition of his work upon the subject, tabulates the results of the examinations of 175,127 persons. Among this number the percentage of those with color blindness amounted to 3·95, and it is hence a fair conclusion that any method of examination which gives a percentage differing from this in any marked degree must be vitiated by some error, either in its own nature or in the method of carrying it into effect.—*London Times Report.*

METHOD OF PRESERVING THE COLOR OF PLANTS IN AN HERBARIUM.

MR. G. C. DRUCE, M.A., F.L.S., some weeks ago read before the Chemists' Assistants' Association (London) a paper on "The History of Botany—Herbaria," in the course of which we find the following:

One great complaint about dry plants is that the color has gone or has become altered, but a great deal may be effected by careful drying. My friend, Dr. Schonland, told me of a plan they had in the Berlin herbarium of dipping the specimen in three parts of sulphurous acid and one of methylated spirit. The flowers are immersed until bleached, or in the case of white ones from a few seconds to seven minutes, according to the texture of the flower; they are taken out, and the superfluous moisture allowed to be absorbed by a piece of bibulous paper, and then dried in the ordinary way. Gradually the color comes back and is then permanent.

The rationale of the process appears to be this. The destruction or alteration of plant color in drying is probably owing to a ferment. We know that hay allowed to ferment or heat becomes spoiled. So with herbarium specimens, overheating or allowing them to remain in damp papers is absolutely destructive to color. Some colors appear to be especially fugitive or sensitive. Blues become brown, whites become brown or black, pinks change to brown, and yellow sometimes changes to green. Now, I take it, the sulphurous acid not only deoxidizes the color, but, combined with methylated spirit, destroys the ferment. On exposure to air, or in process of time, the plant again becomes oxidized and the color reappears. That the spirit may be useful in hardening the cell wall is also probable. There is some difficulty with flaccid flowers, for when dipped in the solution they become so pulpy as to render it very difficult to lay them out properly. Such specimens may be first put in parchment paper, and pressed in it.

It answers admirably for our Campanulaceæ, Orchidaceæ, and also for the parasitic Cuscuta or semi-parasitic Lathræa, Bartsiana, and Orobanche. My experience is that pink colors are generally darkened by it. I am told it answers well for the Cow-wheats and Asperula. My experience with the former is not as yet satisfactory. Care must be taken to use fresh sulphurous acid free from sulphuric. I have found that slight traces of the latter are sufficient to change delicate blues to pink, and thus to give false impressions.

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